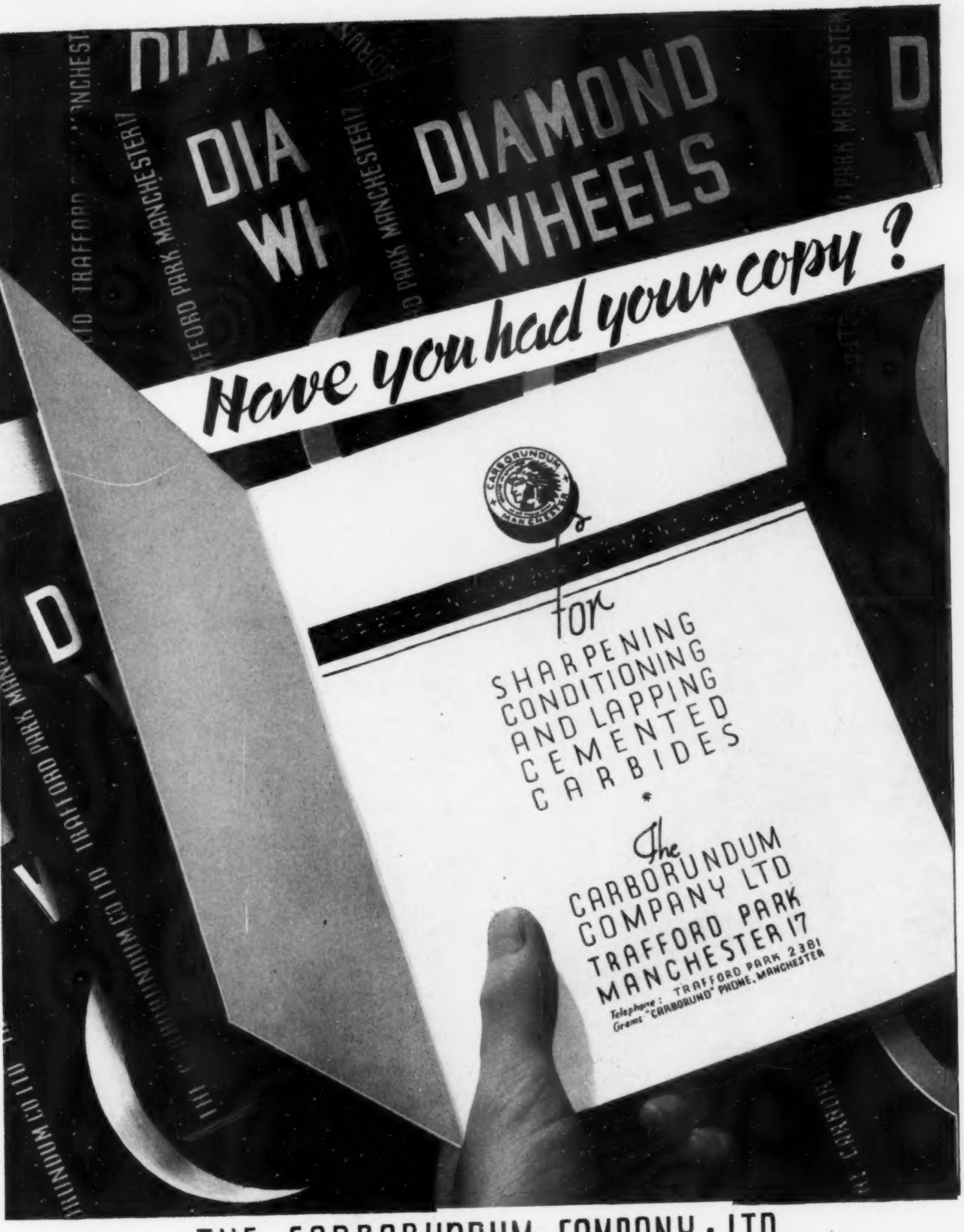
Special STEEL Section

METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 20. No. 117. 669.05 M 562 JULY, 1939 Price 2/- [subscription 24/- per annum, post free.]


DIAMOND
WHEELS
Have you had your copy?
for
SHARPENING
CONDITIONING
AND LAPPING
CEMENTED
CARBIDES
The
CARBORUNDUM
COMPANY LTD
TRAFFORD PARK
MANCHESTER 17
Telephone: TRAFFORD PARK 2381
Grams "CARBORUND" PHONE, MANCHESTER

UNGERER

High Efficiency Plate Straightening Machines

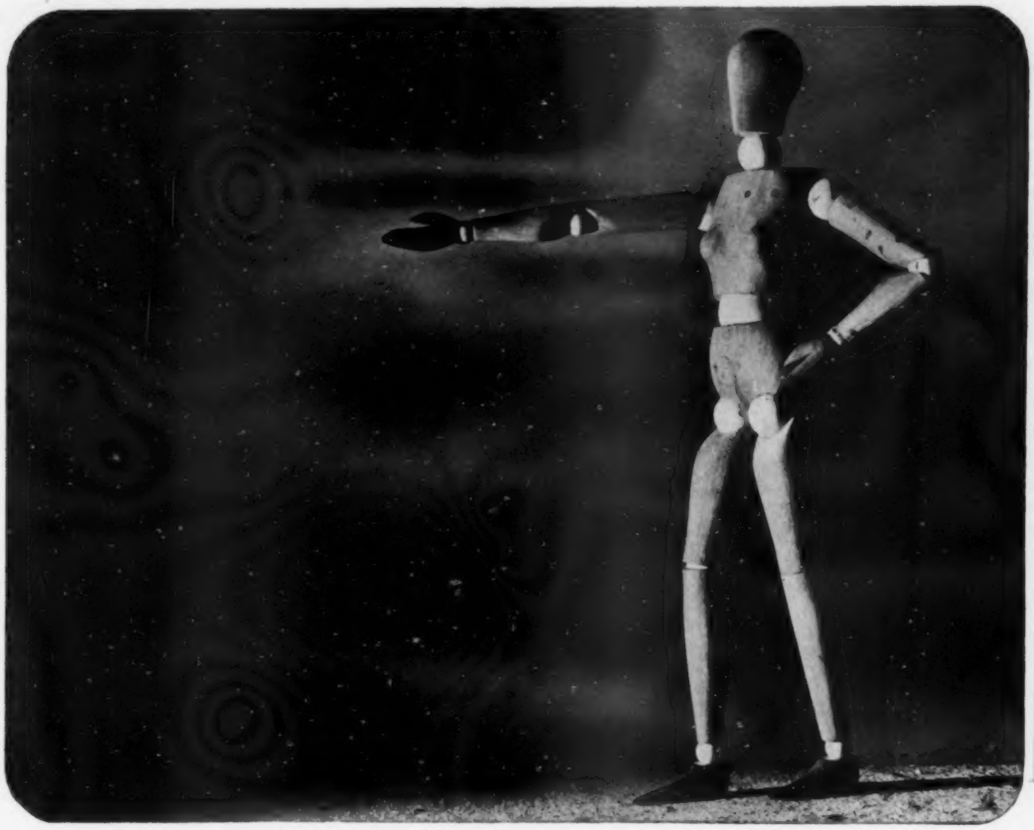
KARL FR. UNGERER

ENGINEERING WORKS

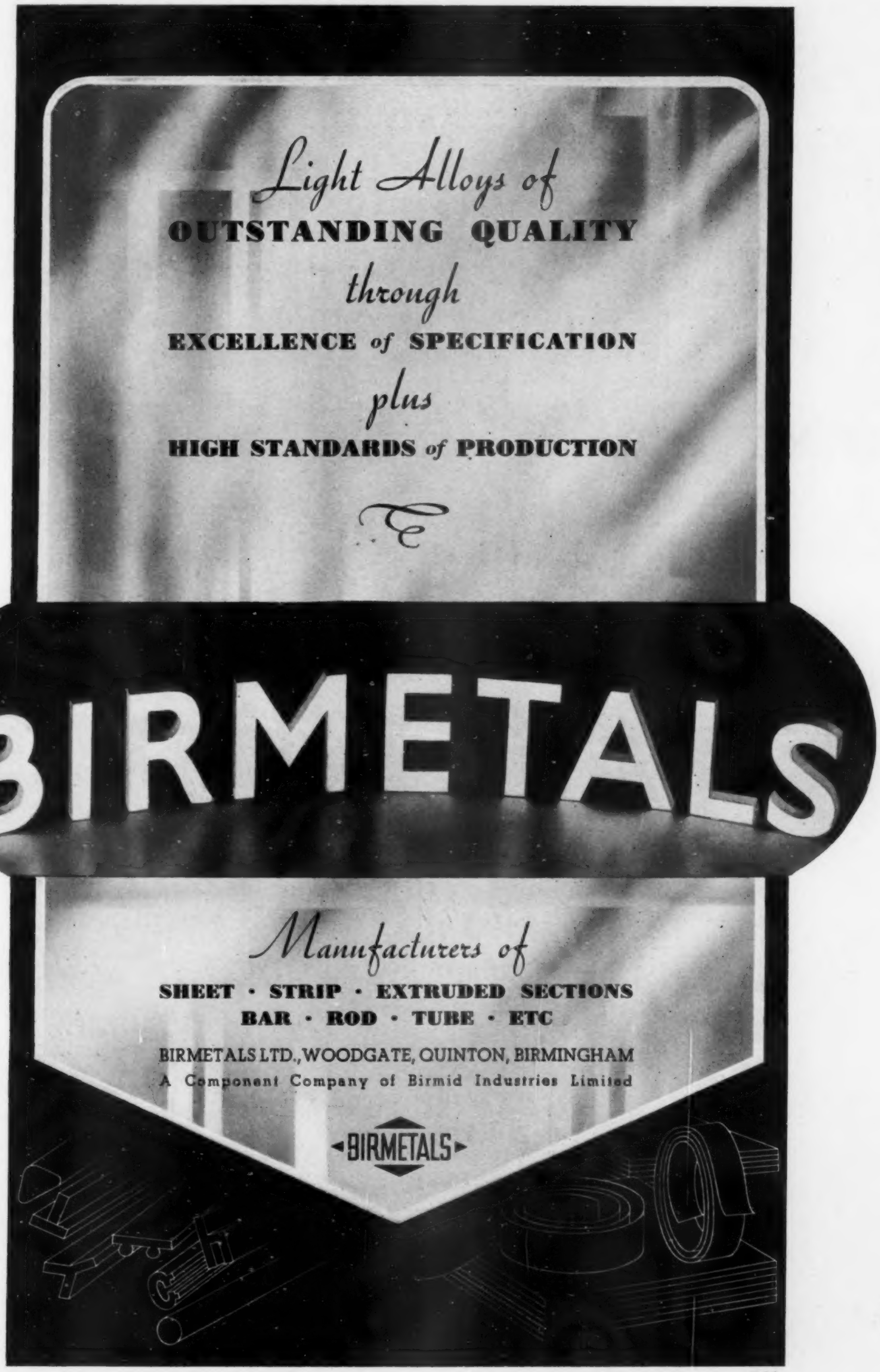
PFORZHEIM-BRÖTZINGEN (GERMANY)

Sole Agents in Great Britain:
INCANDESCENT HEAT CO. LTD.,
SMETHWICK, BIRMINGHAM.

Technical Representative:
EMIL HAAG, 197, HOLLY ROAD
BIRMINGHAM 20.



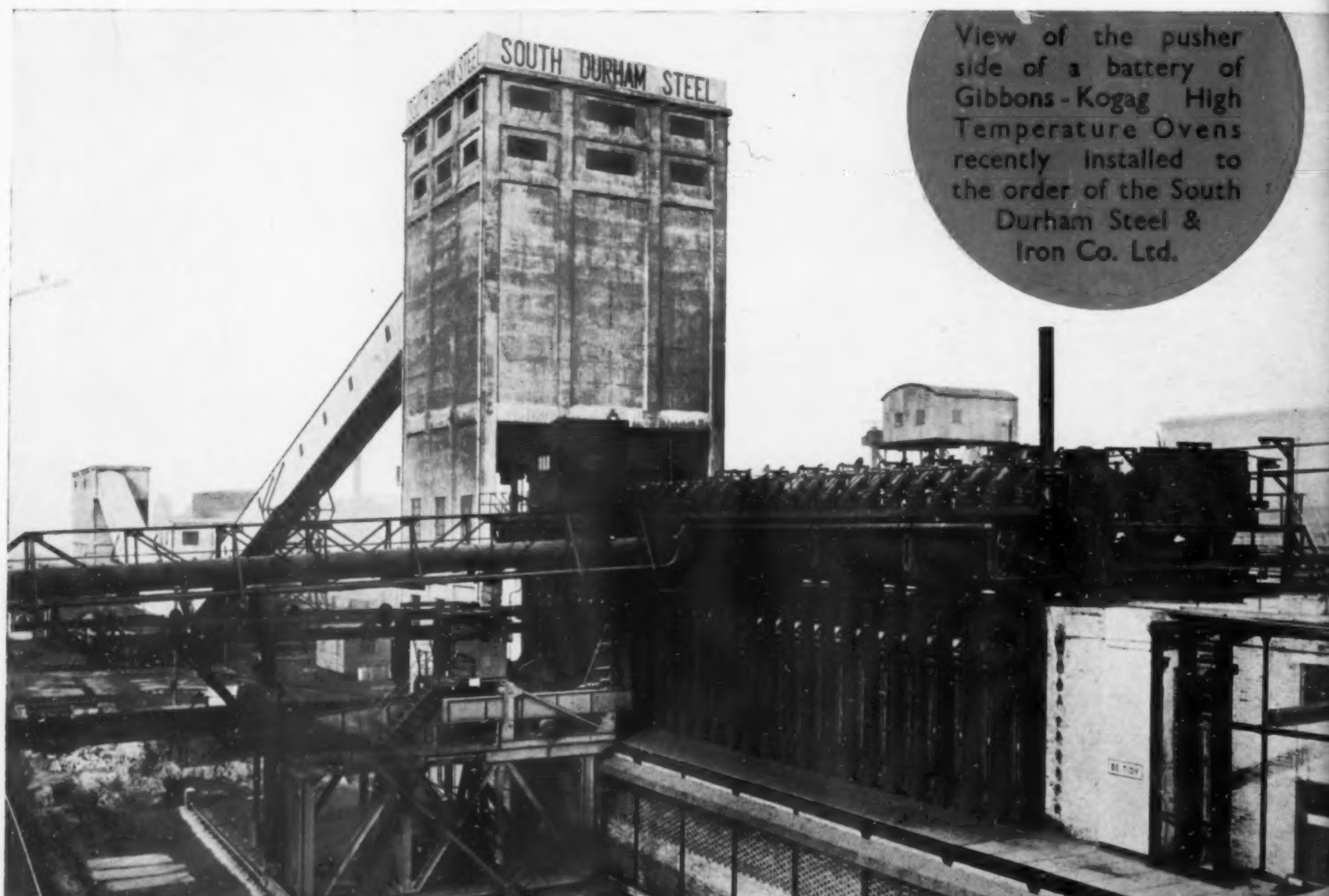
202/18008


Light Alloys of
OUTSTANDING QUALITY
through
EXCELLENCE of SPECIFICATION
plus
HIGH STANDARDS of PRODUCTION
BIRMETALS
Manufacturers of
SHEET · STRIP · EXTRUDED SECTIONS
BAR · ROD · TUBE · ETC
BIRMETALS LTD., WOODGATE, QUINTON, BIRMINGHAM
A Component Company of Birmid Industries Limited
BIRMETALS

T.G.S.

GIBBONS-KOGAG HIGH TEMPERATURE COKE OVENS AND BY-PRODUCT PLANT

GIBBONS



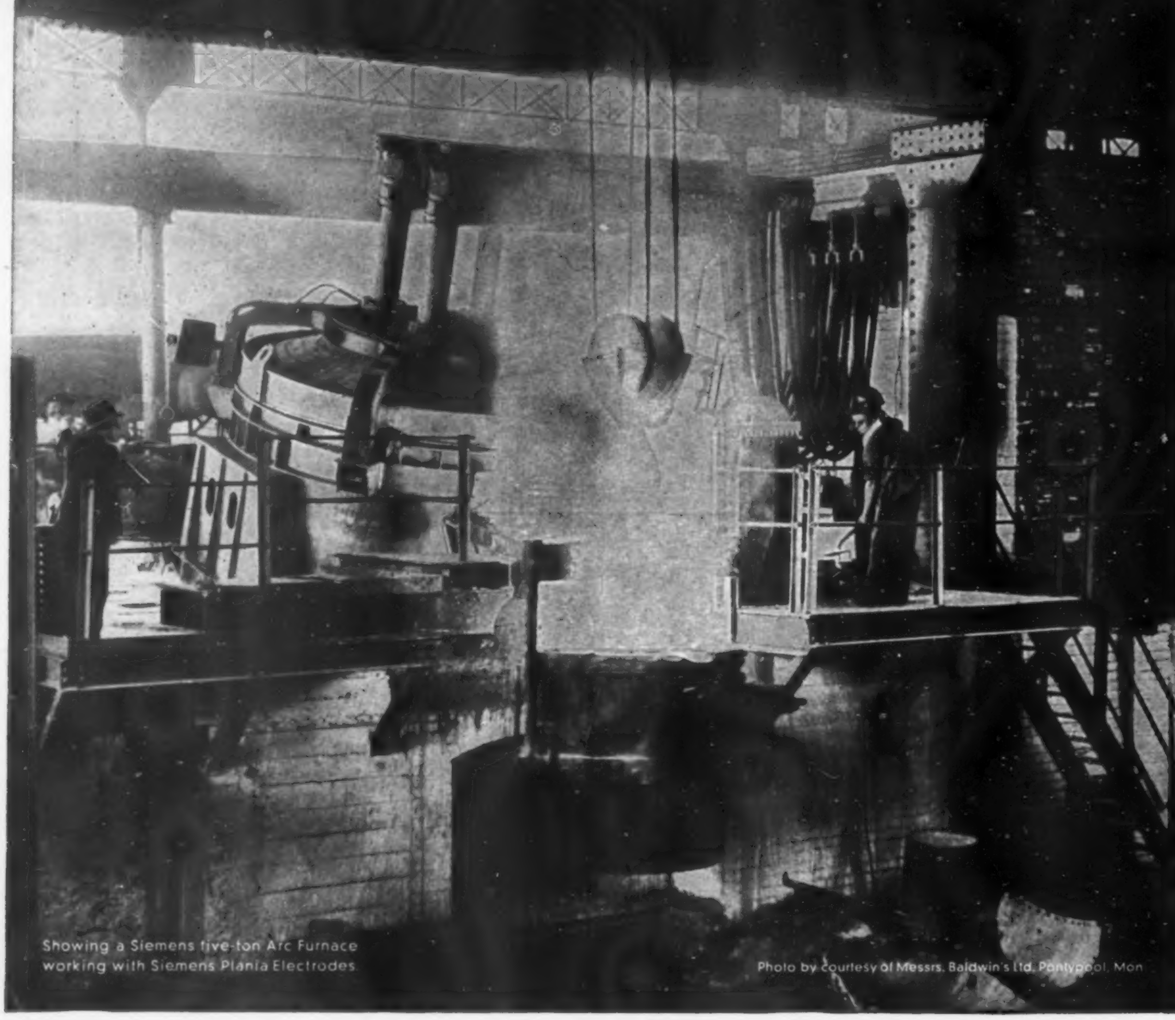
View of the pusher side of a battery of Gibbons - Kogag High Temperature Ovens recently installed to the order of the South Durham Steel & Iron Co. Ltd.

GIBBONS BROS. LIMITED,


Hydraulic Die and Forging Press
having four pressure steps of respectively 7000, 5300, 3000 and 1500 tons
SCHLOEMANN
Schloemann
AKTIENGESELLSCHAFT · DÜSSELDORF

SIEMENS

ARC FURNACES AND ELECTRODES



Showing a Siemens five-ton Arc Furnace working with Siemens Plania Electrodes

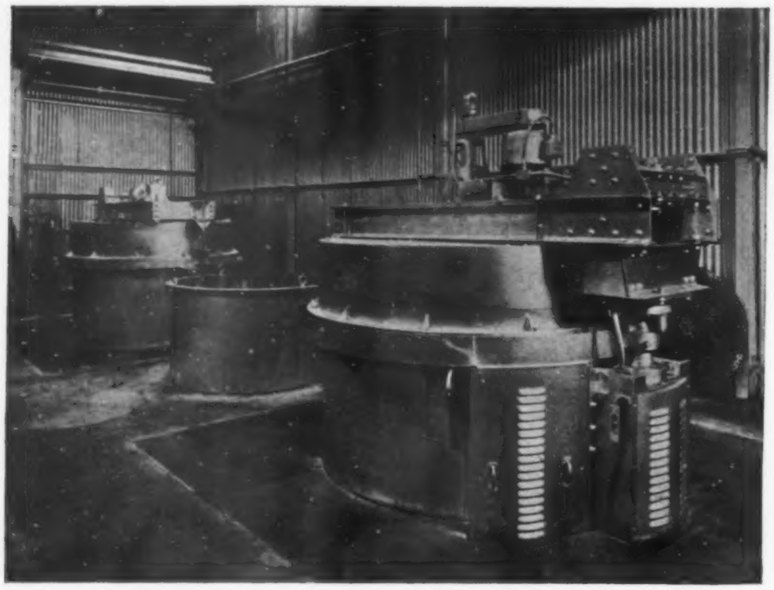
Photo by courtesy of Messrs. Baldwin's Ltd, Pontypool, Mon.

More than 200

Siemens Melting and Reduction Furnaces are working satisfactorily and economically with SIEMENS PLANIA ELECTRODES. We are in a position to supply suitable Electrodes for any Electro-Metallurgical and Electro-Chemical Process.

SIEMENS-SCHUCKERT (GREAT BRITAIN) LTD · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

EFCO Furnaces for the Light Alloy Industry



Typical EFCO vertical forced air circulation furnace for heat treatment of light alloy castings.

We are manufacturers of furnaces for the melting and heat treatment of aluminium and light alloys for the production of sheet, strip, extruded sections, forgings, castings, etc., and amongst the users of our furnaces are the following Companies:

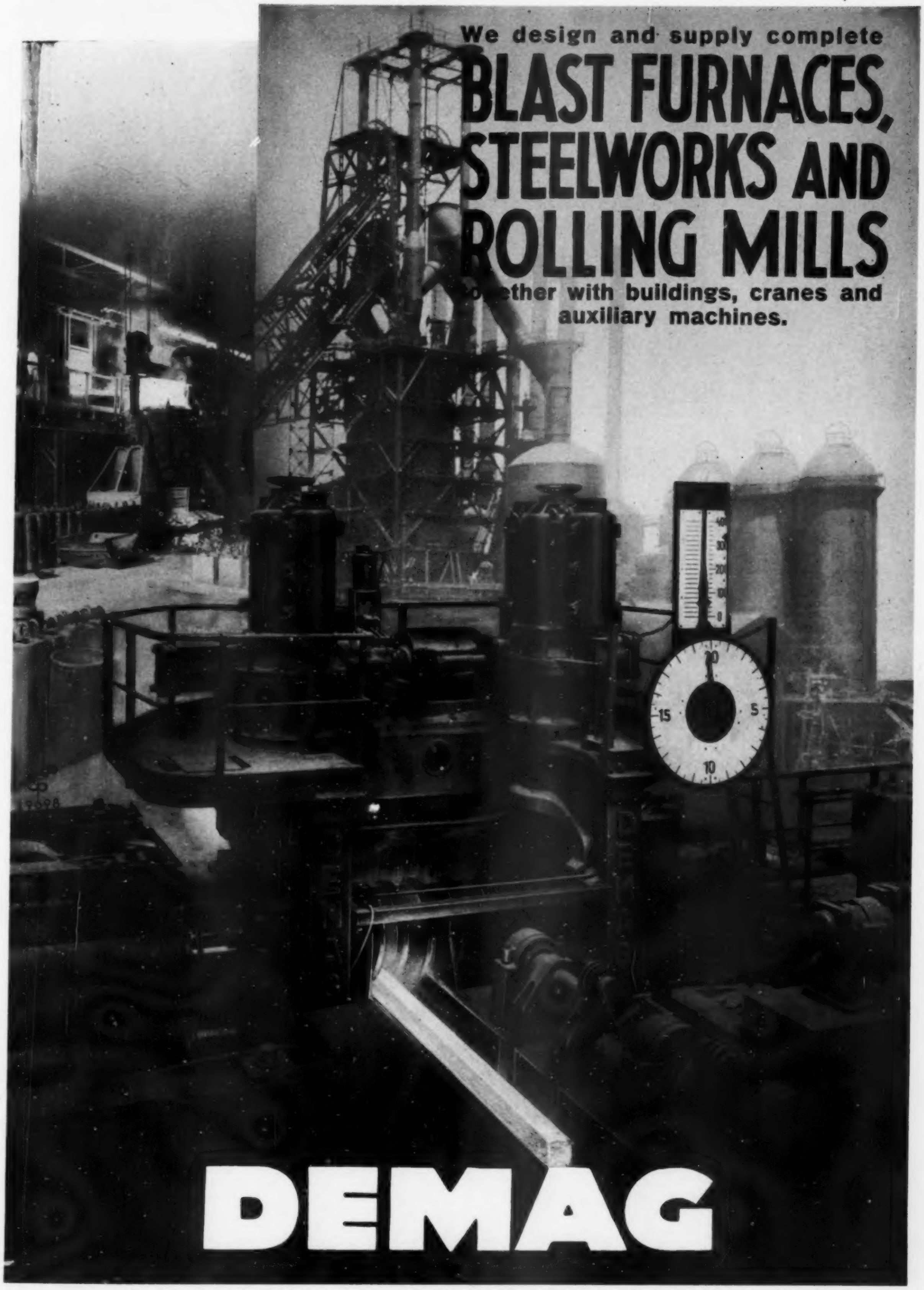
James Booth & Co. (1915) Ltd.
The British Aluminium Co. Ltd.
Northern Aluminium Co. Ltd.
Reynolds Rolling Mills Ltd.
Reynolds Tube Co. Ltd.
Sterling Metals, Ltd.
J. Stone & Co. Ltd.
Birmetals Ltd.

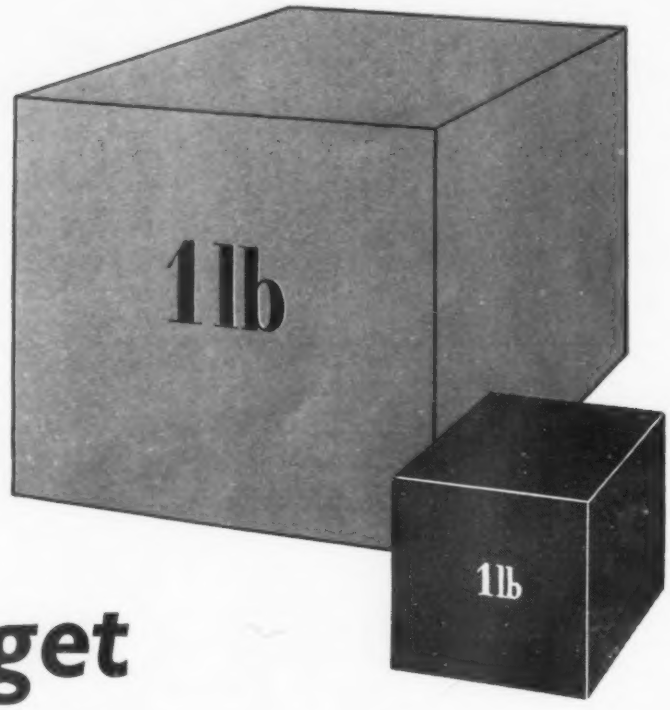
EFCO

ELECTRIC FURNACE COMPANY LIMITED
ELECTRIC RESISTANCE FURNACE CO. LTD.
17 VICTORIA STREET, LONDON, S.W.1

TELEPHONE ABBEY 4171 (7 LINES) **TELEGRAMS ELECTRIFUR, PHONE, LONDON**

Lindum


We design and supply complete
BLAST FURNACES,
STEELWORKS AND
ROLLING MILLS
together with buildings, cranes and auxiliary machines.
DEMAG



You get value for your money with Aluminium

Which is the heavier — a pound of feathers or a pound of lead? There is no reason for you to get caught by this. *Per pound* aluminium costs more — but *per finished casting?* That is a very different matter.

Because aluminium goes approximately three times as far per pound as most other metals, and is easier to machine, the finished casting often costs less; and if there is a fractional extra cost, you get in return all the advantages that only aluminium can provide.

It will pay to take a look round your foundry to see if there are any jobs that could be better cast in aluminium. Our technical department will be glad to help in the solution of any problem that may arise.
Aluminium Union Limited, The Adelphi, Strand, London W.C.2.
Telephone: Temple Bar 7766.

ALUMINIUM UNION LIMITED

HIGH PURITY ALUMINIUM INGOT · FOUNDRY ALLOYS

METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
New Laboratories for the British Non-Ferrous Metals Research Association	87–89
This national organisation of producers, manufacturers, and users of non-ferrous metals, which was centralised in one building in 1930, has developed rapidly and considerable extensions have been made to its laboratories as a result of serious overcrowding. These extensions and the laboratory equipment are described.	
Research and Development	91
The National Physical Laboratory ..	92
Annual Inspection by the General Board.	
Standardised Aluminium Alloys in the United States. By Robert J. Anderson, D.Sc.	93–94
In most countries which manufacture aluminium and its alloys the question of standardisation has become increasingly difficult because of the rapid development and increase in numbers of the alloys available, but some form of standardisation is essential, not only to ensure control in processing operations but also as a check on quality and performance in service. Considerable success in this direction has been achieved in America as this article indicates.	
Free Machining Lead-Bearing Steels	95–98
A small amount of lead added to open-hearth steel has no effect upon the physical properties of the steel except for slightly reduced grain size, but considerably increases the speed at which the steel can be machined, together with additional economy due to the extension of tool life. This type of steel is discussed.	
Chemistry as an Aid to the Production of Sound Castings. By E. Altenhein, D.Eng...	99–100
Steel. By W. J. Brooke	101
The Manifold Uses of Steel. By Dr. W. H. Hatfield	102
Steels Used in the British Railways. By T. H. Turner	103–104
The widespread use of steel in railway tracks, vehicles and auxiliary services are briefly reviewed.	
Tinplate and the Canning Industry. By W. E. Hoare, B.Sc.	105–106
Steels in the Automobile and Aeronautical Industries. By W. H. Hatfield, D.Met., F.R.S.	107–108
The development of these industries to their present state of efficiency is largely due to improvements in quality and range of steels to meet particular demands. The uses of steels in these industries are reviewed.	
Applications of Steel Tubing. By a Special Contributor	109–110
There are very few industries and very few countries in which British steel tubes are not in service; to describe all their uses is impossible, but examples are given which show how widely they are applied.	
Steels for Power Plant. By H. H. Burton	111–113
A selection of steels is discussed which are being used and developed for plant concerned in the raising of steam and its conversion into mechanical energy, and that employed in the conversion of mechanical into electrical energy.	
Modern Tool Steels. By L. K. Everitt, B.Met.	114
Shipbuilding Steels. By J. W. Donaldson, D.Sc...	115–116
Reference is made to the steels used in ship construction together with trends in their development.	
Steel Wire. By Alastair T. Adam ..	117–118
Typical examples from each of several types of steel wire are briefly discussed.	
Recent Developments in Materials, Tools and Equipment	119–120
Trends in the Development of Alloy Steels. By Ed. Houdremont ..	121–123
Attention is directed to the trend of alloy steel development in Germany. The author refers particularly to structural steels, tool steels, stainless and heat-resisting steels, and to special purpose steels, emphasising the need for adding exact quantities of particular alloys in order to ensure desirable qualities.	
The Use of Steel in Heavy Works Plant. By W. Reid	125–126
Application of Alloy Cast Irons to Crushing and Grinding Machinery. By L. Sanderson	126
Business Notes and News	127
Metal Prices	128

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone: Central* 0098.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER."

JULY, 1939. VOL. XX, No. 117.

New Laboratories of The British Non-ferrous Metals Research Association

Euston Street frontage of the new Laboratory Building.

The British Non-Ferrous Metals Association is a national organisation of producers, manufacturers and users of non-ferrous metals established in 1920 for the promotion and use of scientific knowledge in industry. Its administrative, technical and information services were centralised in one building in 1930; since then there has been serious overcrowding in the laboratories and considerable extensions have been made. These extensions, which are described, were officially opened recently by the Rt. Hon. Oliver Stanley, M.C., M.P.

RESEARCH is so widely undertaken to-day, and its technical advantages realised, that the word is often, we think, accepted without full implication of its significance in other directions. Whilst the results of intelligent research provide greater diversity of applications and greater economies in processing, with consequently increased prosperity to the industry concerned, there is an economic aspect which demands consideration. This is, that the operation of large-scale research laboratories means a diversion of capital to a purpose which results in that greater prosperity through the wider use of materials and the application of the products themselves—and that is capital which the investor would possibly be reluctant to lay out in that direction alone.

For those several reasons there is special interest attaching to large and well organised laboratories, such as the laboratories of the British Non-Ferrous Metals Research Association.

This is a national organisation of producers, manufacturers and users of non-ferrous metals, established 19 years ago for the promotion and application of scientific knowledge in industry. It is financed by subscriptions from its membership of some 300, and that income exceeds £30,000 per year when supplemented by a useful Government grant.

The scope of the Laboratories covers researches on problems of interest to all its groups of members and the application of those findings to industrial practice, with surveys and reports on developments in the metal industries, and in scientific metallurgy both at home and abroad. Each major research is under the supervision of a separate committee of members and the development department assists members in applying those results in actual practice. This also means the rendering of assistance to members in solving technical problems, supplemented by an information department which serves the useful purpose of keeping members in touch with the most recent technical developments.

In brief, the organisation comprises a staff of 25 technical experts, 25,000 sq. ft. of laboratory space, £10,000 worth of equipment, and a library of more than 20,000 scientific books and other references.

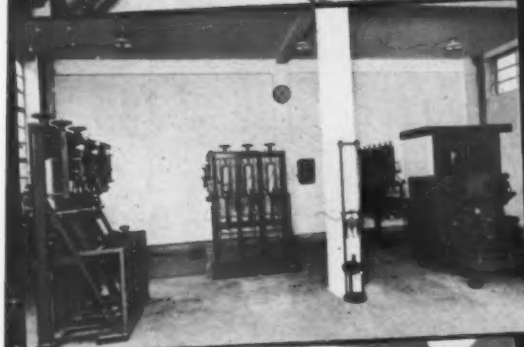
The New Laboratories

Considering these facilities in greater detail we note that the melting shop has five main furnaces—the tops of these furnaces being at floor level, and above which is an overhead runway with lifting tackle—a small high-frequency melting furnace and an electric annealing furnace with hearth capacity of 32 × 20 in. Along one side is a work bench, one section of which serves as a moulding bench, and provision is made for the installation of a small drop-hammer for forging tests.

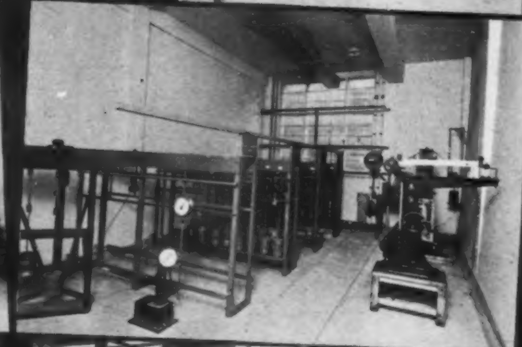
The main furnaces are a natural-draught Morgan coke-fired crucible furnace with capacity of 100 lb. copper; a 27-kVA Efco electric resistance furnace with capacity of 120 lb. copper; a gas-fired crucible furnace, capacity 100 lb. copper, in which air is supplied at a pressure of 20 in. of water by a two-stage fan and an automatic mixing regulator for the gas and air to ensure efficient working over a wide range of melting speeds; a 35-kVA Efco high-frequency furnace of the spark-gap type, being three separate furnaces with maximum capacities of 22 lb., 11 lb., and ½ lb. copper, and a fourth furnace coil is provided for melting a maximum of 2 lb. copper in vacuo or in

Left.—Part of the melting shop, showing the high-frequency furnace

Right.—Part of the mechanical testing laboratory showing some of the general testing equipment.



Left.—High temperature creep units in the mechanical testing laboratory.



Right.—The constant temperature room with creep test frames.

Left. — Spectrographic equipment in the physics laboratory.

Right.—Part of the microscope room.

Left.—The pyrometry and heat-treatment laboratory.

Right.—Showing apparatus for determination of oxygen in metals, in a special chemistry laboratory.

controlled atmospheres ; a 21-kVA Birlec electric resistance annealing furnace with Cambridge thermostatic temperature control, capable of maintaining a constant temperature up to 1,000° C. Further, there are a number of small gas-injector and wire-wound electric furnaces for small scale working.

The original melting shop is now used for galvanising and welding. The experimental galvanising pot is $3\frac{3}{4} \times 10 \times 13$ in. deep internally and has a capacity of a little more than 100 lb. of zinc. It is electrically heated. Above it runs a runway and pulley block. Welding facilities comprise gas-welding equipment and power supply for electric equipment.

The mechanical testing laboratory occupies all the working space in the semi-basement of the new building, completed early this year, and at one end has a constant-temperature room. Tensile tests are made on Amsler 20-ton hydraulic universal machine with seven ranges, from 20 to 0·2 tons ; on an Avery single-lever machine with split counterpoise providing ranges of 5-ton and 1-ton ; and on a small Avery lever machine which was originally a wire-tester but has been modified for making tests on softer materials such as lead and lead alloys at both high and low temperatures.

A standard Vickers diamond hardness tester is used, and a standard Izod machine is installed for impact tests. The latter is adopted for such tests at high temperatures on specimens supported at both ends. Three units are used for fatigue tests : a Wöhler type machine designed and constructed in the Association's laboratories, for use either with single-point or two-point loading, speed 3,000 r.p.m. ; a Haigh-Robertson standard wire fatigue

tester with speed variation up to 15,000 r.p.m.; and a reverse bending machine which can be used for testing sheet or pipe, either as simple cantilevers or subjected to uniform bending moment over a portion of the length. Speed of operation is 1,450 r.p.m.

Three machines, also, are used for cupping tests, comprising a standard Erichsen unit; a Guillery machine on which the K.W.I. cupping test, the Erichsen type test, and the Jovignot fluid-pressure test can all be carried out; and a special machine for determining the tensile strength and ductility of thin metal foils by fluid pressure.

The creep testing equipment is comprehensive. There are high temperature creep test units for loads of 1 or 2½ tons; apparatus for determining creep resistance of lead pipes at elevated temperature and under internal pressure provided by gas from cylinders; six frames, each of which accommodates 20 specimens for subjection to dead load up to 350 lb.; Barr and Bardgétt stress-relaxation creep test equipment, fitted with a weigh bar on which the load can be read to 0·001 ton, and with temperature control; and another of the Association's own design of machine for creep tests under repeated loading and unloading at room temperature with load period variation. Also in the mechanical testing laboratory are a hydraulic ram, with variable speed control, for internal pressure tests up to 15,000 lb./sq. in., and a refrigerator for temperatures down to $-40°$ C.

The machine tools in the machine shop have now been arranged for individual drive by 3-phase a.c. motors and a welding and brazing hearth provided. Equipment includes a 6-in. precision lathe with a range of speeds from 30 to 1,500 r.p.m.; 6½ in. and 3¾ in. screw-cutting lathes; a 3½-in. bench lathe; a 12-in. stroke Butler shaping machine; a horizontal milling machine; a vertical driller, power hacksaw; bandsaw; pedestal tool grinder; a marking-out table; and a guillotine on which sheet steel up to 18 gauge can be cut.

One of the most interesting sections is the physics laboratory which, with 900 sq. ft. area, contains equipment for spectrographic analysis, general physical testing (by Tinsley Kelvin double bridge), thermal conductivity determinations; specific gravity determination of large castings; and the quantitative measurement of specular and diffuse reflectivity. There are three Hilger spectrographs and a non-recording micro-photometer, the latter increasing the accuracy of spectrographic analysis by giving a quantitative measurement of the intensity of particular lines in the spectra. The smallest of these spectrographs is used for the routine analysis of lead, the middle sized instrument for general applications, and the largest—an automatic Littrow instrument—for the analysis of metals and alloys with complex spectra.

In the two rooms available for micro-examination and metallographic preparation there are two Watson bench metallurgical microscopes and a low-power stereoscopic binocular microscope for the examination of coarse structures and fractures and for other specimens where great depth of focus is necessary. Photographic work is catered for by a large Vickers projection microscope magnifying from 3 to 2,500 diameters, and by normal type cameras. The preparation room has orthodox equipment for polishing and etching the micro specimens.

The pyrometry and heat-treatment laboratory is independent of the heat-treatment facilities in the melting shop and is equipped for the heat-treatment of smaller specimens, and the standardisation of thermocouples by means of a Tinsley potentiometer. The general application furnaces include a high-temperature resistance furnace with non-metallic resistance rods; a thermostatically controlled wire-wound furnace, and two electric ovens, also thermostatically controlled, for temperatures up to 350° C. and 150° C. respectively. To cater for experimental work in respect of oxidation and scaling there are a considerable number of small furnaces. The pyrometric

Part of the corrosion laboratory.

equipment includes a number of Cambridge thread recorders among which is a thread-recording millivoltmeter.

Special methods of analysis and development work are undertaken in the chemistry laboratories, and these comprise a main laboratory and four adjacent smaller rooms. In the main laboratory there are electric and gas heated hot plates in a fume cupboard; central benches with high pressure water for filter pumps, and vacuum filtration facilities. The side benches are devoted to titration work. The four smaller rooms comprise a balance-room; a room for electrolytic and colorimetric estimations in which is a small rectifier supplying d.c. up to 12 volts for electro-analyses, a Lovibond tintometer and Nesslerizers; a laboratory for operations requiring comparative freedom from acid and ammoniacal fumes, containing air and steam ovens, electric combustion-furnace, Bone-Wheeler gas-analysis apparatus, and apparatus specially designed for the determination of small quantities of oxygen in metals; and a laboratory with draught cupboard for those operations involving the use of noxious gases.

Corrosion is one of the factors which calls for detailed research and is here undertaken in a main laboratory of some 800 sq. ft. floor area and a smaller laboratory for special operations. It is noticeable that both are clean in layout, fixtures having been kept to a minimum and the cupboard and bench equipment provided by teak-topped units which can be rearranged easily for various types of work.

Apparatus includes jet-test equipment for investigation of the resistance of condenser tubes to attack by rapidly moving aerated sea water; a special still for producing unusually pure sea water; two glass degreasing units; thermostats for making corrosion experiments at controlled temperatures—the capacity of each thermostat is approximately 3 cu. ft.—glass circulators for studying the resistance of galvanised hot water tanks, working on the thermo-syphon principle; and electrolytic stripping apparatus for measuring weight, thickness, and structure of zinc coatings on wire and sheet. In the small laboratory are a centrifuge, microscopes, micrometers and spherometers, also reagents and apparatus for microchemical work. Electrochemical work is also undertaken in this smaller laboratory and the apparatus includes a Cambridge thread recorder for measuring the potentials of corrosion electrodes in conjunction with a compensated four-electrode valve potentiometer; electrometer valve potentiometer for pH determinations; Wheatstone bridge for measuring conductivity of electrolytes; and various auxiliary instruments.

Library and Development Department

There is a comprehensive library containing some 4,000 books and bound volumes as well as more than 20,000 leaflets and reprinted matter; and a development department which really forms an exhibition of the results of the

Association's researches. This department gives a very clear indication of that work, illustrating the effect of impurities on the properties of copper; casting of strip brass ingots; properties of alloys for high temperature service; copper locomotive fire-box stays and plates; properties of lead, with special reference to cable sheating and building services; galvanising process; corrosion research in many directions; electrodeposition of metals; the casting of non-ferrous metals and alloys, including aluminium alloys, bronzes and nickel silver; the properties of soft solders, and various aspects of welding. In this latter respect, the investigation into the weldability of non-ferrous metals was undertaken in collaboration with the Institute of Welding.

Corrosion Resistance of Dissimilar Metal Couples

DETAILED tests on the corrosion resistance of dissimilar metal couples were carried out at the Miami seawater rack of the U.S. Air Corps, and provided much useful data relative to the many dissimilar metal joints which are unavoidable in modern airplane construction.*

The materials tested were aluminium sheet, various aluminium alloy sheets, naval brass, cadmium-plated naval brass, chromium-molybdenum steel, cadmium-plated Cr-Mo steel, Monel metal and rivets of aluminium and of aluminium alloy. The test pieces were placed in racks and exposed for six months, being immersed in this seawater (of 2.5% sodium-chloride content), at high tide and exposed to atmosphere at low tide. It will be realised that there was a natural agitation effect included.

Aluminium or aluminium-alloy rivets were used to fasten all the attachment plates to the panels used. The influence of various insulating media for different metal couples was also investigated; this showed clearly that such insulating materials were of undoubted value. Neoprene tape seemed to be the best for general application, and zinc chromate primer was considerably superior to iron oxide.

Whilst the chromium-molybdenum steel (X-4130), produced severe attack on all four of the aluminium alloys to which it was fastened, this corrosion attack was almost completely eliminated when the steel plates were cadmium plated. This was noticed also in the case of brass—when cadmium plated the attack was virtually eliminated.

An interesting point arising from consideration of the effect of cadmium plating was that the durability of the coating varied. On both the brass and steel attachment plates this cadmium coating was still intact on plates in contact with three of the aluminium alloys but on the same plates in contact with one of those three alloys anodised, the cadmium had been removed entirely and corrosion of the base metal had taken place.

The aluminium alloy (24ST specification), showed far more severe rivet corrosion. Reverse-bending tests were used to determine any effects on physical properties. It was shown that in the case of the panel which had the various aluminium alloys as attachment plates, there was no reduction of physical properties either in the panel or the seam areas of the three alloys, but that the anodised 24ST panel showed a loss of some 20% in the panel proper, with many instances of the seam areas being stronger than the panel. It was noted that all the aluminium-alloy attachment plates used for this test were anodic to the 24ST sheet and would give protection to the sheet in the seam areas.

The current-potential measurements did not agree throughout with the actual seawater tests, which indicated that the laboratory tests did not reproduce every condition of actual exposure, and did not, therefore, suggest that current-potential measurements were of doubtful application. In any dissimiliar metal couple, the rate of corrosion is proportional to the magnitude of the current flowing in the cell, and it is often maintained that the relative magnitude of this current, and therefore, the subsequent corrosion probability, can be estimated from the open-cell voltage, as calculated from the single potentials of the metals forming the couple. But actual results showed several divergences from that basis. In the rivet series, where the corrosion was found to be in agreement with potential measurements, the relation between the anode and cathode areas of the cell is a determinative point. The same potential, it is stated, obtains between 24ST rivets on 2S sheet as with 2S rivets on 24ST sheet, the 2S material being the corroding electrode in both cases; but in the first case the entire panel forms the large area corrosive productive anode and there is little apparent damage, but the concentrated attack resulting from the small area of the 2S rivets and its relatively high anode current density produces severe attack in quite a short time.

Variations in corrosion of rivets used on alloy sheet of the same specifications were possibly caused by differences in rates of quenching of sheets and rivets, or of strains resulting from the cold working of the metal during riveting.

* *Ind. and Eng. Chem.* Vol. 31, No. 5, p. 608.

Diamond Wheels for Cemented Carbide Tools

THE need for highly-finished edges for maximum life between grindings is recognised by the users of cemented carbide-tipped tools. Reconditioning often follows the phases of rough grinding, semi-finish grinding and lapping with diamond powders. Most tools can, however, be satisfactorily reconditioned with a single operation on a diamond wheel and even where tools are badly chipped or where an extremely fine finish is essential not more than two grinding operations on a diamond wheel should be needed.

Now, that is a big saving—in time and in cost. The claims for these advantages for the carborundum diamond wheels are justified; further, they are supplemented by the longer tool life which results from the stock removal without wheel vibration, that quality being due to the free-cutting property of the diamond wheel. Less stock need be removed at each grinding, geometrically correct surfaces are obtained, and there is no tendency to check or crack the tip of the tool as there is no pounding of the wheel against the tip.

The advantages and economies of the diamond wheel are well presented in this publication. In regard to economy the manufacturers of the diamond wheel say that "off hand, it might appear that to perform a grinding operation with an abrasive of pure diamond would be too costly for commercial purposes . . . the savings made in the grinding time involved in the reconditioning of cemented carbide tools will, when figured in money spent for direct labour plus overhead, in practically all cases, more than pay for the diamond wheel itself. In many cases the direct labour saving alone, without the overhead, will pay for the wheel. All other savings are therefore clear profit."

This booklet deals with the Carborundum brand diamond wheels for sharpening, lapping and conditioning cemented carbides. With its many photographs, its diagrams, and its specific instructions it forms a very useful handbook for the operator; it shows, also, how to choose the appropriate type of wheel and the best methods of using a diamond wheel for best possible results in each application or purpose. The sections on recommended practice cover off-hand grinding, chip breakers, surface grinding, cylindrical and internal grinding, and stoning.

The 60-page book is available to readers. Application should be made to the Publicity Department of the Carborundum Co., Ltd., at Trafford Park, Manchester.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Research and Development

IT is doubtful whether any other materials have had greater effect upon man's progress than metals, so closely are they bound up with almost every aspect of human activity. Transport and communications as we know them, and machinery of every kind, are wholly dependent on metals. The generation and distribution of electricity, the building of ships, motor cars and aeroplanes, are only a few of the examples which depend on the provision of suitable materials with which the engineer can work. The tremendous improvement in performance of aircraft in the last twenty years is due in great measure to the skill of the engineer, but without suitable metals and alloys he would be powerless. Many engineering improvements depend upon the availability of alloys with improved properties in some particular direction and engineering advances must often wait upon metallurgical developments.

Discovery and invention do not spring full-grown from the brains of man, they are the products of long and arduous research, and their application is the result of much experimental investigation during which they are developed and improved. Research in the metallurgical industries with the constant object of providing new and better materials is, therefore, as vital as is research in engineering or other industry connected with man's material progress. Actually, the labour of many men, great laboratories, and long, patient, scientific experiment are involved in building up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact, some day brings forth a revolutionary discovery, an illuminating hypothesis, a great invention. Research, both in pure science and in its application to the arts, is one of the most potent impulses to progress, for it is organised research which gives daily improvement in plant, machines and processes, in methods of agriculture, in the protection of health, and in understanding.

The importance of research to industrial progress is generally acknowledged. It was interesting to note, for instance, that Lord Hirst of Witton, in his address at the recent annual meeting of the General Electric Co., Ltd., commented on the help resulting from the success which the Company's research and development engineers have attained by their intense efforts. He was referring to the Company's export trade, which had exceeded the record figures of the previous year, and to the strenuous efforts being made to trade with foreign countries, in which the Company has, in some cases, found satisfactory openings for doing business. Progress and improvement, he said, have been achieved in almost every section of the works.

But, while research and development have long been in progress, the Great War provided a tremendous stimulus and caused Great Britain, as well as other countries, to intensify scientific investigations, particularly in the case of metals. The accomplishments of metallurgy in the improvement of quality of products, in the development of new products, and in lowering their cost, impressed many firms and caused them to provide special facilities for scientific research. In addition to the establishment of many excellent research laboratories by large firms, however, national industrial research organisations have been established and have expanded with great rapidity to keep abreast of the times and to anticipate the future.

An outstanding example of national research establishments which has made rapid progress since the War is the National Physical Laboratory, which attracted many British scientists and technical workers on the occasion of the recent annual inspection by the General Board. The work dealt with in this Laboratory covers a very wide field and includes all branches of physics, electricity and magnetism, radio communications, engineering, metallurgy and chemistry, aeronautics and ship design in relation to form and propulsion. In recent years, a considerable amount of the work of the metallurgy department in the Laboratory has been given to the production of pure metals. Modern metallurgical research has shown that the removal of impurities to the level that has been achieved in producing such metals as aluminium, copper, zinc, lead and cadmium, may appreciably affect their engineering and industrial properties. Apart from work of a fundamental character, the work of this Laboratory is of immense importance to industry, since it is concerned with new problems which are continually being presented in establishing facts which can be applied to industry.

All sections of British metallurgical industry are fully alive to the vital necessity of providing new and better materials and have become increasingly research-minded. Much of the work is specialised and separate research organisations, working on a co-operative basis, have been established to concentrate on special sections of the industry. One of these, the British Non-Ferrous Research Association, founded immediately after the War, has made such progress that new laboratories were necessary to facilitate its activities. These were officially opened recently by the President of the Board of Trade, the Right Hon. Oliver Stanley, M.C., M.P., and are described elsewhere in this issue.

This Association, as in the case of a number of similar organisations, conducts long-term researches on technical problems of common interest to groups of subscribing members. The work covers a wide field including such different aspects of the manufacture and use of non-ferrous metals as the production of sound castings, the development of alloys with improved mechanical properties at atmospheric and elevated temperatures, electroplating and the production of alloys and methods of treatment to reduce corrosion. In addition to the Association's experimental research, its information and development services are of great value. Through the information service, members are kept informed on the latest published information, while the special duty of the development section is to bridge the gap between research and industry, and to help to ensure the utilisation of the results of research. This latter work includes discussions and demonstrations of the way in which such results can be used on a manufacturing scale and assisting manufacturers in any modification in works plant or procedure.

Fundamental scientific research has had a profound influence in the development of new and improved products and in the contribution of metallurgy to the progress of engineering. The accomplishment of these organisations are a legacy of inestimable worth, and there is every indication that they will continue to be of great service in assisting to maintain the scientific and technical prestige of this country and in promoting engineering and industrial progress.

National Physical Laboratory

Annual Inspection by the General Board

ON the occasion of the recent annual inspection of the National Physical Laboratory by the General Board, some 1,500 technical representatives of industry from all parts of Great Britain visited Teddington to review the work of the laboratory and the advances made during the year. The visitors were received by Sir William Bragg, O.M., President of the Royal Society and Chairman of the General Board; Lord Rayleigh, Chairman of the Executive Committee; and Dr. C. G. Darwin, Director of the Laboratory. Special exhibits demonstrating the work were staged in all the departments.

The many exhibits of the Physics department included an apparatus for measuring the temperature of steel. In the method devised, a thermocouple is immersed directly in the steel while still in the furnace. Earlier attempts on these lines failed because the heavy sheathing, believed to be essential for protecting the thermocouple, proved too expensive for routine work. The feature of the new method is the use of a very light and cheap silica sheath, which enables the thermocouple to be plunged into liquid steel so as to give a reading of temperature in a few seconds, and to be withdrawn intact. The method is applicable not only to furnaces of various types, but to molten steel at various stages after being tapped from the furnace. It is now in use at a number of steel works.

An interesting exhibit in the Engineering Department indicates the work involved in the development of materials for high-temperature applications. The "creep" or continuous flow of metal when it is hot and subjected to prolonged loading is of great practical significance in such cases as boiler plant, steam turbines, aero engines and certain chemical plant. Thirty-four testing machines are in use to measure the "creep" of various materials at different temperatures and stresses, in order to obtain satisfactory evidence of the probable distortion by "creep" of the materials when put into service. The amount of "creep" in a given time is very much influenced by the presence of alloying elements in steels and by differences in heat-treatment; these and many other aspects of the subject are being investigated. In the Metallurgical Department most of the investigations fall into one of two groups. One group is concerned with steels, especially those intended for use at high temperatures, as in steam boilers, turbines and superheaters. The other group deals with alloys of the two light metals, aluminium and magnesium, which are of the greatest importance in the construction of aircraft. Many of the advances made since the war in the use of these alloys are due to the work of the Laboratory. In connection with the former group an apparatus was shown, by means of which the action of superheated steam on steels under constant stress may be studied. The steel specimens were in the form of hollow "thimbles," stressed in tension by the internal pressure of steam, and maintained at a constant temperature by external heating in a regulated atmosphere. After the experiment, the scale formed on the steel is measured and examined microscopically.

The work on light metals exhibited was concerned with age-hardening in aluminium alloys. Alloys of aluminium containing 4% of copper have been investigated in the form of single crystals. X-ray photographs were exhibited, which show the initial stages of hardening to consist in the separation of small groups of copper atoms from the mass of the crystals, the groups forming sheets along certain crystal planes. After being formed at a low temperature, a short heating causes them to disappear, and at the same time the alloy loses its acquired hardness. Continued heating leads to the formation of larger groups, and the hardness again increases. Finally, a second crystalline phase is produced.

It has only been possible to refer very briefly to some of the exhibits, but it will be appreciated that, in addition to the routine testing of instruments and materials, and the investigation of particular industrial problems, the Laboratory also carries out a programme of research on a number of broader questions which affect the well-being of the community as a whole or which are of interest to industry in general.

New Methods for the Production of Aluminium

IN recent years Germany has made great progress in the production of light metals, but the basic practice in the industrial production of aluminium has not greatly altered, bauxite still being the most important raw material. In Germany, the desirable grade of bauxite has to be imported, but she possesses other raw materials such as kaolins, clays, etc., in addition to poor quality bauxite, which could be used. A number of alternate processes for aluminium production have been proposed, but the majority have met with little success.

In the current issue of the Bulletin of the Imperial Institute it is stated that, in the case of raw materials, such as kaolins, clays, etc., the so-called acid processes such as the Nuvalon process of Buchner and the S.T. process of T. Goldschmidt A.-G., Essen, seem most promising. Large-scale experiments with the Nuvalon process were unsuccessful, largely owing to the difficulty of finding containers capable of resisting the attack of nitric-acid corrosion. On the other hand, the S. T. process has been so developed that at present large amounts of clay are treated at the Lautawerk with satisfactory commercial results. The alumina produced is more expensive than that obtained from bauxite by the Bayer process, but the same plant can be adapted without difficulty so that it is possible to change from bauxite to clay at any time.

Aluminium Alloys, their Characteristics and Applications to Wrought Form

HERE is a book which goes far beyond the sales promotional purpose for which it was apparently intended and which gives a wealth of information in the characteristics and applications of wrought aluminium on the characteristics and applications of wrought aluminium alloys. This new publication is a treatise on wrought aluminium. It deals with aluminium and its alloys in general, describes briefly, but clearly, current practice in the manufacture of wrought alloys, gives some very useful pages on available alloys—their selection—and characteristics, fabrication and finishing—production of pressings, spinning, soldering, welding, riveting and rivets, machining, electroplating and anodising—and the applications of such alloys.

The various applications of wrought aluminium alloys are classified under the main headings of aeronautical, automobile, marine, railway, electrical, radio-engineering, architecture, chemical plant, the food industry and domestic appliances.

In addition to ample illustrations, there are diagrams and tables where needed. Further, there are nearly 40 pages of tables—which alone would make this book valuable for reference purposes—and to make this still more useful, the tables are preceded by an index. A few selections from the index to these tables should serve to show the value of the material—bend radii; heat-treatment temperatures; mechanical properties of heat-treated alloys, forgings, tubing, work-hardened alloys; comparisons of physical and mechanical data of various materials; standard tolerances, and sizes and weights of tubing. There are, of course, conversion and other useful tables.

This publication has been produced for distribution to markets outside Great Britain only. It is by the Aluminium Union Ltd., Adelphi, Strand, W.C.2.

Standardised Aluminium Alloys in the United States

By Robert J. Anderson, D.Sc.

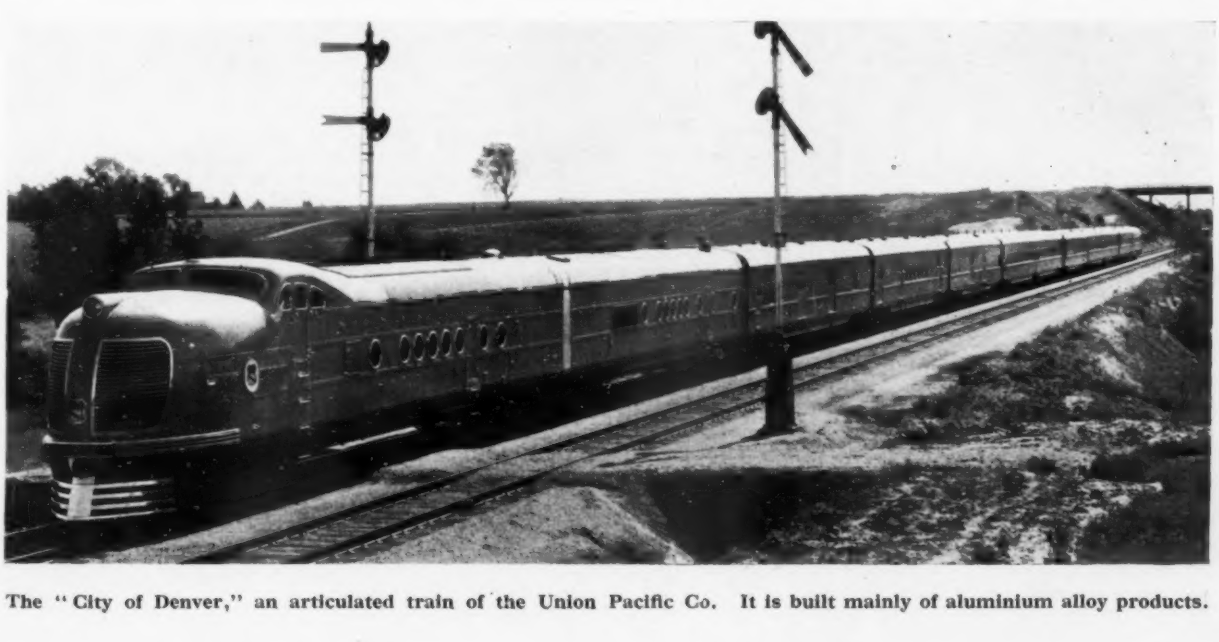
In most countries which manufacture aluminium and its alloys the question of standardisation has become increasingly difficult because of the rapid development and increase in numbers of the alloys available, but some form of standardisation is essential, not only to assure control in processing operations but also as a check on quality and performance in service. Considerable success in the standardisation of these alloys has been achieved in the United States of America, as this article on the subject indicates.

REMARKABLE progress has been made during late years in the industrial development of light aluminium alloys, notably of compositions with special properties, and for particular applications. Various new aluminium alloys which are better, in certain respects, than older ones have been introduced. Some of these new alloys have been standardised under engineering specifications, and have been used in large quantities for manufacturing sundry products, both cast and wrought. Others have been employed only to a small extent. As a general result of recent advances, the number of aluminium-base compositions utilised in practice has considerably increased. Also numerous new specifications have been drawn to cover different products made of aluminium alloys.

So many aluminium-base alloys are now offered in the market, and so many specifications for their use in various manufactures have been issued, that the problem of choice is often quite perplexing to both present and potential consumers. Most properties of any two aluminium alloys differ more or less—in the majority of comparisons very greatly,—depending upon the composition, method of manufacture, heat-treatment, and other controlling factors. Besides, some specific composition is better suited than another for one or more applications. The properties and qualities are markedly affected by the composition in particular, and manufacturers are enabled to provide a wide range of properties in aluminium-base products. Thus, as the number of merchantable alloys has been multiplied, selection has become increasingly difficult. At the same time compositions especially well adapted for a diversity of special purposes may now be chosen with discrimination.

It is often said that there are too many aluminium alloys employed in practice, that a large number could be dispensed with, and that numerous compositions are unnecessarily complex. Broadly, this is all true. On the other hand, there are good reasons why a great variety of alloys have been developed for use in manufacturing. For example, as fresh knowledge has been gained from research, it has been possible to produce new and improved aluminium-base materials. Furthermore, it has frequently been necessary to alter the composition of standard alloys, so as to better the casting or working qualities. Also, some aluminium-alloy compositions have had to be specially contrived in order to meet the requirements of certain applications. Finally, other alloys have been devised with the view to evading patents.

As is the case with ferrous and non-ferrous materials generally, recognised technical bodies have established standards, or specifications, for most of the aluminium alloys which are used appreciably in practice. Ordinarily, a new alloy is employed for some time in manufacturing work before specifications covering it are issued by national boards or engineering societies. But producers have, meantime, standardised the material, and experience of it has been acquired by both them and consumers. Accord-



The "City of Denver," an articulated train of the Union Pacific Co. It is built mainly of aluminium alloy products.

ingly, the issuance of a specification by an organisation representing divers interests (producers, consumers and the public) indicates that a demand exists, and that the alloy, or manufacture thereof, as standardised, meets certain trade requirements.

Standard specifications afford a guide in choosing aluminium alloys for various purposes, inasmuch as the limits of composition and certain minimum properties are stipulated. Further guide is available in some specifications where industrial sizes of products, together with dimensional tolerances, are included. As a rule, the engineering standards which have been established are very helpful. But reference to a series of specifications for a number of aluminium alloys and manufactures may not necessarily or readily solve the problem of choice in the case of a proposed application. It is usually advisable to get the recommendations of producers and often any additional information, based on experience, as may be obtained. Of course private specifications, set by consumers, are frequently worked out in co-operation with supplying manufacturers.

The development of specifications for particular compositions of aluminium alloys to be used in producing certain types of manufactures has simplified the problem of selection. Standards have been drawn for various alloys to be employed for sand, die and permanent-mould castings; forgings ; sheet and plate ; bars, rods and wire ; extrusions ; and rolled shapes. Also, in some American specifications, there are included explanatory notes, wherein may be designated definite purposes for which different aluminium-base compositions can be satisfactorily employed or which indicate the general field of approved use. Moreover, in the United States there has recently been a tendency toward the formulation of recommended practices for the handling and utilisation of aluminium alloys, among other materials. Such recommendations as issued by engineering societies are found of much assistance in selecting compositions for many applications. Of course valuable information and advice concerning suitable alloys for any feasible uses are readily to be obtained from aluminium producers and manufacturers.

The object of this paper is to present, briefly, the current situation as to specifications for and the use of standardised aluminium alloys in the United States. While only limited data can be given here, enough can be included to show what alloys are being mainly employed. In addition, the principal sources of American specifications are mentioned.

American Specifications

In the United States, specifications for aluminium alloys and products made thereof have been issued by the foremost manufacturers and consumers, national engineering organisations, and departments of the Federal Governments. Among other sources of these standards or specifications the following may be noted : Aluminium Company of America, the American Society for Testing Materials, the Federal Specifications Executive Committee (formerly the Federal Specifications Board) in the Procurement Division of the Treasury Department, Army, Navy and the Society of Automotive Engineers. Besides, standards have been established by secondary aluminium interests, aircraft manufacturers, sand foundries and die-casting concerns, motor-car companies, and various fabricators.

On the whole, corresponding specifications issued by different American sources are more or less similar, and many are identical. Numerous private specifications are the same or practically the same as those of national bodies, and the former are tending to be eliminated. In the United States the bulk of output in aluminium-base products is now made in accordance with standards set by the Aluminium Company of America, with the specifications issued by the American Society for Testing Materials, and with certain specifications defining performance as agreed between producers and consumers of ingot, semi-finished manufactures, parts and other wares. As a practical matter, these specifications are mostly coincidental.

Various classifications for aluminium alloys are established in the United States as in the case of other countries. Thus, these materials are classed specifically in respect of composition, mechanical or physical properties, use, performance under different conditions of service (for example, resistance to corrosion), suitability for casting or working, etc. But, of course, a combination of qualities is normally considered in assigning a composition to any category. American specifications and standards may be divided in the same way. The general type of specifications for aluminium alloys as drawn in this country has been previously indicated.

Aluminium alloys are broadly divided into two main classes, namely, compositions for castings and compositions for wrought products. A few may be used for both kinds of manufactures, but most casting alloys are not suited for working. Casting alloys are subdivided into two classes—that is, compositions for as-cast products and for those to be heat-treated. In the case of the former, alloying of itself suffices to yield properties satisfactory for various purposes. Heat-treatment is applied in the case of the latter in order to improve the mechanical properties of the alloys as cast. Also, the casting alloys are grouped in other classes, depending upon the kind of casting process to be employed, namely, sand, pressure-die and permanent-mould. Some aluminium alloys are used in all three processes, but a number have been developed especially for die-casting and for permanent-mould casting.

Aluminium alloys for working are likewise subdivided into two classes. The compositions are grouped chiefly in accordance with their susceptibility to solution heat-treatment. In one class improved mechanical properties are obtained primarily by cold work after annealing, and the manufactures are produced in a range of tempers. In the other class, heat-treatment is applied as a rule in order to enhance the mechanical properties of manufactures as wrought. Desirable combinations of properties within wide limits are secured by regulating the composition and heat-treatment. Further, wrought products in the latter class of alloys may be strain-hardened by cold work after heat-treatment. Special compositions of aluminium alloys have been developed for different types of working—for example, forging and extrusion.

Some American standards and specifications for various aluminium alloys, and products thereof, will be summarised in the next issue.

(To be continued.)

Leningrad Institute of Mining

The School of Mining, now known as the Leningrad Institute of Mining, is about to celebrate the 165th anniversary of its foundation. The School is only eighteen years younger than the Moscow University, which is the oldest Russian higher-educational institution.

The School of Mining has an interesting history attached to it. In 1771, a Ural industrialist named Tasimov appealed to the authorities to open a school for " the education of persons in matters relating to mining and the management of factories." In the archives of the Leningrad Institute of Mining is the original ukase signed by Catherine II in 1774, authorising the foundation of " a school to teach sciences relating to mining and the smelting trades." Later, the school was transformed into the Mining Cadet Corps.

To-day, the Institute of Mining is one of the biggest higher-educational institutions in the U.S.S.R. for geological research and the sciences relating to mining and metallurgy. Some of the most outstanding of Soviet scientists studied at the Institute—Academicians Karpinsky, Pavlov, Gubkin, Obruchev, Kurnakov, Zavaritsky, and others.

In the chairs of the Institute are 43 professors, 93 lecturers and 83 assistants. The Institute claims to have the biggest mining museum in Europe.

Free Machining Lead-bearing Steels

A small amount of lead added to open-hearth steel is stated to be dispersed uniformly in such a fine state that it cannot be seen under the microscope, in which form it has no effect upon the physical properties of the steel except for slightly reduced grain size, but considerably increases the speed at which the steel can be machined, together with additional economy due to the extension of tool life. This type of steel is discussed.

IN recent years considerable attention has been given to the development of metals and alloys possessing high strength, ductility and toughness, improved resistance to fatigue, corrosion, abrasion and erosion, and the advance in metallurgical knowledge has largely contributed in meeting these requirements of the engineer. To-day modern engineering equipment incorporating these metallurgical developments possess remarkable capacity for service, resistance to corrosion, abrasion, etc., according to the purpose for which it is intended; but no sooner are particular service conditions met by suitable materials than new and more-severe conditions are presented by engineers, making the need for progress in metallurgical research a modern necessity.

Coupled with metallurgical developments is the increasing attention given to speed in engineering production, especially as a result of the advent of the composite carbide cutting tools, which have so greatly increased the output from machine tools. To make adequate use of the carbide cutting tools, machine tool manufacturers have designed and produced machines that enable cutting speeds to be used formerly thought impossible. Efforts have also been made to improve the machinability of steel, with a view to increasing the cutting speed still further and raising the capacity of modern machines. Much work has been carried out to effect improved machining, and the type of steels known as free-cutting steels were developed. The use of sulphur, phosphorus, silicon, nitrogen, and to some extent manganese, in steels to promote free machining characteristics were developed, and are being applied for this purpose, particularly free-cutting steels containing sulphur or phosphorus as essential constituents.

The results achieved with these free-cutting steels have been remarkable; unfortunately, however, the field is somewhat restricted, as the principles on which these improvements are based cannot be universally applied to the wide range of carbon and alloy steels in general engineering use because of the adverse effect on toughness, corrosion resistance, forgeability, or response to heat-treatment, either separately or in combination, according to the method adopted to improve machining. A new approach to this problem has resulted in the addition of a small percentage of lead to open-hearth steel, and tests show that the machinability of the majority of steels to which this addition is made is improved by as much as 60%. Probably the most important feature of this development is that the chemical and physical properties of the particular steel remain substantially the same as when untreated with lead.

The deliberate introduction of lead, an element hitherto not intentionally used in conjunction with steel, was complicated by the fact that it is considered to be insoluble in solid steel, and only slightly miscible in the liquid condition, but, by the application of the results of carefully planned research, problems encountered were overcome and the homogeneous distribution of the lead was rendered possible. As a result of these investigations production methods were standardised, and the qualities obtained by the addition of lead can be repeated with regularity from cast to cast. Investigation by means of the microscope, examination of electrical properties, and the application of X-ray methods, indicate that the lead is present in the steel principally as metallic lead in a very finely divided state of submicroscopic size.

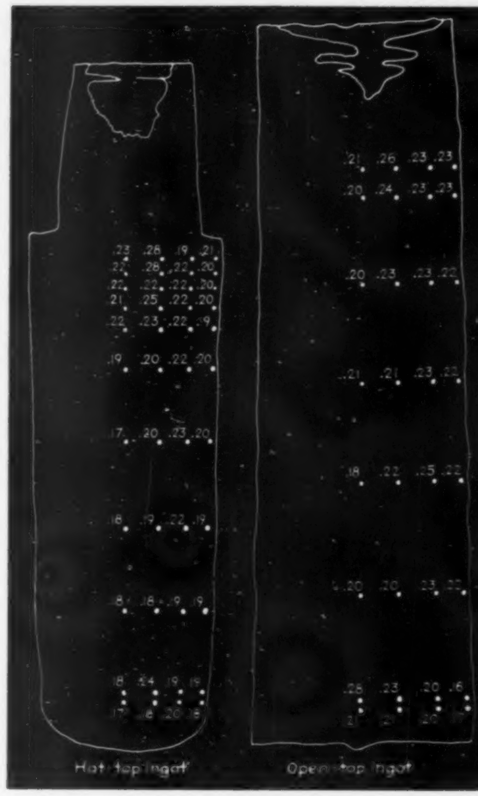


Fig. 1.—Lead analyses across sections of two types of ingots of lead-bearing steels.

The effect of lead inclusions in improving machinability has been indicated by Robbins.[1] Although the amount is very small—0·20 to 0·25%,—its influence on machining is most marked, and the method of adding the lead is applicable to the manufacture of all steels made by melting and ingot casting methods. Large-scale production tests of a number of grades of steel, including free-cutting, mild and carbon steels, and several alloy steels, all show decided improvement in machinability. According to Nead, Sims and Harder,[2] an improvement in machinability can be noted when less than 0·10% lead is present, with increasing effect as the amount is increased up to almost 0·50%. Slightly under that amount appears to be the limit for uniform dispersion.

Experiments on "over-leaded" steels, in which agglomerations are present, show them to have slightly poorer physical properties than the steels in which the lead is uniformly dispersed. Analyses of specimens taken from different parts of the ingot show a lack of segregation, particularly when the lead content is low. As will be noted in Fig. 1, which shows sections of two types of ingots containing from 0·20 to 0·25% lead, specimens tested give evidence of very slight enrichment of lead in those

1E. J. Robbins, "Character of Machine Performance of Lead-bearing Steels." *Iron Age.* Vol. 142, pp. 28-33.

2J. H. Nead, C. E. Sims and O. E. Harder, "Properties of Free-machining, Lead-bearing Steels. *Metals and Alloys.* Vol. 10, pp. 68-73.

parts of the ingot latest to solidify, or where advancing crystallisation tends to trap parts which remain liquid. It is noteworthy, however, that the distribution of the lead is more uniform than is normally the case with carbon, manganese or sulphur.

It is generally stated that lead is insoluble in solid or liquid steel, and to determine whether it can be held in true solid solution in ferrite, steels containing lead were examined for the usual effects of change in electrical conductivity, or of lattice dimensions. No detectable change in conductivity appears, and X-ray diffraction patterns show no change in lattice dimensions. Either lead is not in solid solution in appreciable amount, or it fails to show the expected influence. Critical point determinations show no clear effect.

From the evidence of uniform dissemination and apparent lack of solid solution, it appears probable that the lead is present in a submicroscopic state of subdivision, analogous to the dissemination of particles in a precipitation-hardened alloy or a grain-size controlled steel—i.e., in a very different order of size and far more uniform dissemination than is the case in leaded brass. Indirect evidence pointing in this direction is the fact that emulsified lead has a slight grain refining effect on steel.

Many of the free-machining steels obtain their improved machinability by the addition of some element, or by a special method of processing which interferes with other properties of the steels so treated—makes them more brittle, reduces their ductility and impact resistance. This reduction in mechanical properties places limitations on their applications, and any development in method of improving machinability must be critically examined in respect to its effect on the mechanical properties of the steel.

Tests indicate that the outstanding feature of the lead-containing steels is that their mechanical properties are almost indistinguishable from similar lead-free steels. This is evident from results given by Nead, Sims and Harder with regard to early experimental work on screw stock steels, reproduced in Table I. A set of comparison commercial screw stock steels were given impact tests over a range of temperatures. The compositions of the steels were :

	C.	Mn.	S.	P.	Si.	Lead.
B	0·18	0·73	0·111	0·021	0·015	None
A	0·18	0·81	0·134	0·022	0·015	0·13
C	0·18	0·74	0·191	0·022	0·015	0·25
D	0·18	0·75	0·127	0·021	0·014	0·26

The specimens were normalised from 870° C., and the results of Charpy impact tests are given in Table II. The effect of cold-drawing these steels was also studied by drawing down to 0·448 in. diameter a tapered bar, 0·450 in. diam. at one end, 0·505 in. diam. at the other, and making Izod impact tests. The results are shown in Table III. Tests at 10, 20, 40, 80 and 160 days after drawing showed no appreciable change in impact properties. The results which are averaged in Table III indicate that the presence of lead in such steels does not alter their response to cold-drawing.

TABLE II.
AVERAGE RESULTS OF CHARPY IMPACT TESTS ON LEADED SCREW STOCK. CHARPY (KEY HOLE) IMPACT STRENGTH—FT.-LB.

Test Temperature, °F.	Steel B. No Lead.	Steel A. 0·13% Pb.	Steel C. 0·25% Pb.	Steel D. 0·26 % Pb.
600	30·1	22·5	20·5	27·0
500	32·3	29·8	23·0	30·8
450	31·7	27·2	23·4	29·1
400	32·7	28·5	26·4	30·0
350	34·3	31·0	26·0	32·2
75	36·5	34·8	29·9	34·9
32	33·3	33·3	26·5	35·1
0	29·7	33·8	25·8	33·7
—25	27·3	29·5	24·0	27·6

TABLE III.
IZOD IMPACT IN FT.-LB.

% Cold-rolled.	B. No Lead.	A. 0·13% Pb.	C. 0·25% Pb.	D. 0·26% Pb.
3·1	67	66	55	68
6·5	56	54	45	58
10·1	49	46	39	50
13·4	45	45	37	45
16·5	42	41	34	43
9·5	40	39	33	41

The absence of appreciable effect on the mechanical properties of these steels caused investigations on stronger steels, with a view to determining the effect of small amounts of lead. Steels containing 0·46% C, 0·78% Mn, 0·025% P, 0·03% S, 0·18% Si—one being lead-free, the other containing 0·23% lead—were made up into hot-rolled 2-in. diameter bars. The bars were quartered and 0·505 in. specimens cut from them ; these were heat-treated in 0·01 in. oversize. Endurance specimens were 0·27 in. diameter. The specimens were drawn back to 255 Brinell and machined to size and showed :

	Tensile.	Yield.	Elongation.	R.A.	Endurance Limit.
No Lead	121,500	86,000	19·0	54	64,000
0·23% Pb.	121,500	85,000	17·5	51	64,000

The endurance curves are shown in Fig. 2, from which it will be noted that the endurance limits are identical. Further indication that the practical identity of behaviour of this lead-containing and lead-free standard steel extends over the usual range of drawing temperatures for both

TABLE I.
COMPOSITION AND MECHANICAL PROPERTIES OF COLD DRAWN† EXPERIMENTAL SCREW STOCK STEELS.

Heat No.	Composition, %. C.	Mn.	Si.	P.	S.	Pb.	Yield Strength, Lb. per Sq. In.	Ultimate Strength, Lb. per Sq. In.	% Elongation in 2 in.	% Reduction in Area.	Charpy Impact.	Brinell Hardness Before Cold-Drawing	After Cold-Drawing.
2962	0·11	0·63	0·012	0·017	0·19	—	75,100	75,700	17·0	55·5	23·0	104	149
2966	0·10	0·55	0·012	0·019	0·20	0·12	72,000	73,500	18·5	56·5	20·0	105	141
2967	0·11	0·59	0·010	0·017	0·21	0·26	73,100	73,900	18·0	55·0	19·0	100	133
2968	0·11	0·58	0·010	0·019	0·21	0·34	71,100	72,500	19·0	56·0	19·5	99	135
2969	0·11	0·62	0·008	0·017	0·23	0·48	73,200	73,900	18·0	52·0	18·5	101	144
2965	0·12	0·57	0·014	0·018	0·10	0·09	70,700	70,800	20·0	58·0	24·5	95	134
2974	0·14	0·69	0·248	0·019	0·20	—	76,800	78,400	16·5	52·5	19·5	115	156
2963	0·11	0·68	0·238	0·020	0·21	0·09	75,300	77,000	17·5	53·0	22·0	103	152
2973	0·11	1·19	0·228	0·020	0·19	—	81,000	79,700	17·0	54·5	22·0	118	151
2975	0·12	1·2[illegible]	0·203	0·020	0·20	0·09	79,000	79,000	19·0	56·0	31·5	113	143
2964	0·15	1·11	0·010	0·020	0·20	0·09	75,600	75,100	16·5	55·5	23·0	111	133
2991	0·10	0·29	0·104	0·016	0·26	0·39	71,500	75,800	17·5	50·5	17·0	105	143

† Approximately 7% in one pass.

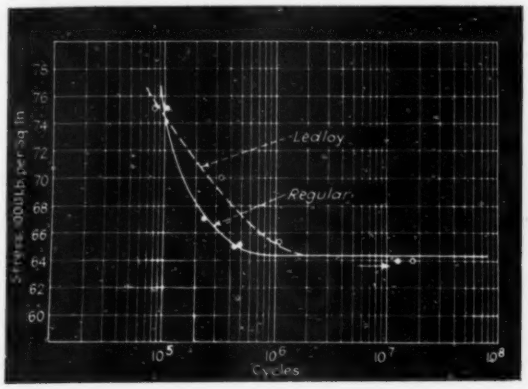


Fig. 2.—Endurance curves for a standard steel with and without lead, water-quenched and drawn to 255 Brinell.

TABLE VI.
LOW-CARBON S.A.E. STEELS, COLD-DRAWN.

Type.	Lead.	Tensile.	Elongation.	R.A.	Brinell.	Charpy, Ft. Lb.
2315	—	104,000	15	56	187	35
2315	0·17	103,000	14	53·5	189	33·5
3115	—	89,000	20	67	170	48·5
3115	0·14	88,000	20·5	64	169	45
4320	—	126,000	12·5	53	226	27·5
4320	0·12	125,000	12·5	52·5	229	28·5
4615	—	106,000	14·5	58	185	40
4615	0·18	108,000	14	56·5	189	36
6115	—	82,000	23·5	70	149	55
6115	0·16	83,000	22·5	68	156	47·5
Hi-Steel	—	102,000	16·5	48	183	17·5
Hi-Steel	0·18	105,000	15	54	189	11·5

water- and oil-cooled specimens is shown in Figs. 3 and 4.

To determine the behaviour of lead in alloy steels, an experimental series of S.A.E. steels were prepared, each being tested with and without lead. The low-carbon alloy steels in this series are given in Table IV, and the mechanical properties of these steels, in the normalised condition, and after cold-drawing 7%, as given by Nead, Sims and Harder, are shown in Tables V and VI. High carbon steels were also tested as annealed, and also oil-quenched and drawn, and the results showed no appreciable difference in the mechanical properties of those containing lead and similar steels without lead.

Improved Machinability

The effect of small inclusions of lead on the machinability of steel is most marked. Both laboratory and production tests show a considerable difference in the machining properties of lead-free and lead-bearing steels, which are otherwise of similar composition, the lathe showing great

TABLE V.
LOW-CARBON S.A.E. STEELS NORMALISED IN ¾-IN. DIAMETER.

Type.	Pb.	Normal Temp., °F.	Tensile.	Yield.	Elongation.	R.A.	Brinell.	Charpy.
2315	—	1,500	86,500	58,000	31	63	163	44
2315	0·17	1,500	88,000	62,500	31·5	61	163	39
3115	—	1,600	79,500	57,000	33	70	146	55·5
3115	0·14	1,600	79,000	60,500	34	67·5	149	49
4320	—	1,600	115,000	80,000	21	57	207	35
4320	0·11	1,600	115,000	77,500	21	65·5	207	33
5120	—	1,700	76,000	56,000	35	68	131	48
5120	0·12	1,700	75,500	54,000	35	66	137	51
6115	—	1,700	75,000	59,500	35	73	131	58·5
6115	0·16	1,700	75,000	58,000	35·5	70·5	126	53
Hi-Steel	—	1,700	84,000	64,000	31	57	152	24
Hi-Steel	0·18	1,700	84,000	64,500	30	56	156	22·5

TABLE IV.
S.A.E. STEELS CONTAINING LEAD.

Type.	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Mo.	V.	Cu.	Pb.
2315	0·17	0·65	0·27	0·027	0·014	3·47	—	—	—	—	0·17
3115	0·16	0·59	0·25	0·024	0·011	1·25	0·65	—	—	—	0·14
4320	0·20	0·53	0·14	0·023	0·013	1·75	0·65	0·33	—	—	0·11
5120	0·20	0·57	0·21	0·024	0·010	—	0·75	—	—	—	0·12
6115	0·15	0·58	0·21	0·026	0·010	—	0·91	—	0·18	—	0·16
Hi Steel	0·20	0·54	0·10	0·029	0·120	—	—	—	—	1·0	0·18

Fig. 3.—Graph showing physical properties of a standard steel, water-quenched, with and without lead.

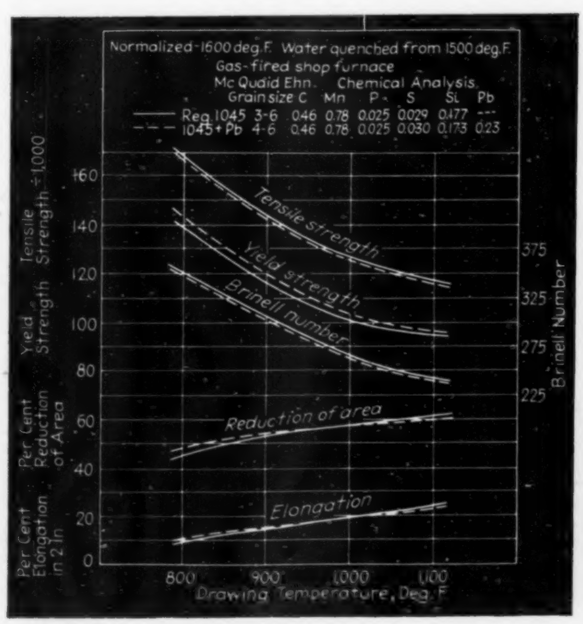
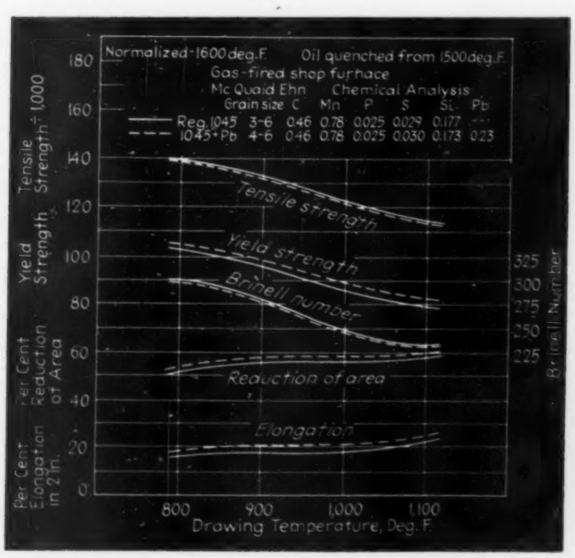


Fig. 4.—Graph showing physical properties of a standard steel, oil-quenched, with and without lead.



improvement. The cause of this improved machinability is probably twofold, the lead acting as a chip breaker in a a similar manner to manganese sulphide, and also as a lubricant, minimising wear between tool and chip, and reducing the heat generated during chip formation.

There are several ways by which machinability may be assessed; thus, for instance, the cutting life of a tool may be measured under standardised conditions of speed, feed, cut and coolant; the measurement of power absorbed in cutting under the same standardised conditions; the calculation of the pressure generated at the tool edge; the heat generated in cutting; and the condition of the machined surface produced by the cutting tool represent a few. In order to make satisfactory comparisons, it is obviously necessary to eliminate the variables as much as possible other than the one being investigated. In comparing lead-bearing with non-leaded steels, therefore, one portion of a cast was untreated, and the other given a lead addition; the test bars selected from each portion being rolled and subsequently treated under identical conditions.

Samples of non-leaded steel containing 0·15% carbon, 1·10% manganese, 0·095% sulphur, and 0·035% phosphorus, and of a similar steel containing in addition 0·20% lead in cold-drawn condition, were subjected to cold-sawing tests. A new saw blade was used for each sample bar; a constant load on the blades was maintained for 10 cuts, and the pressure increased by 50% for a further 10 cuts. No coolant was used, and the number of strokes were taken per standard depth of cut measured. The average results from these tests were as follows:

	Machinability Index.	Index at 50% Heavier Load.
Lead-bearing steel*	165	155
Non-leaded steel	100	100

* Ledloy by Exors. of James Mills, Ltd.

Further tests were carried out to determine the heat generated when making comparisons between samples under similar conditions with regard to turning speed, feed and depth of cut, using a standard knife tool without a coolant. Comparisons were made with standard high-sulphur free-cutting steel, mild steel, and 0·40 to 0·45% carbon steel, each with and without lead addition. The tests gave the following results:

Material.	As Drawn.	Colour of Chips.
Standard high-sulphur free-cutting steel	Lead-bearing	Pale straw
Ditto	Non-leaded	Full blue
Mild steel	Lead-bearing	Straw
Ditto	Non-leaded	Blue
0·40 to 0·45% carbon steel	Lead-bearing	Straw
Ditto	Non-leaded	Purple

Samples of the 0·40 to 0·45% carbon steel, with and without lead, were submitted to tool pressure tests under constant conditions, with regard to speed, feed, cut and the tool angles employed. The index pressures, calculated from tangential radical and longitudinal pressures, were found to be as follows:

Material.	Normalised.	Index Pressure.
0·40 to 0·45% carbon	Lead-bearing	121
Ditto	Non-leaded	145

Tool-wear tests were also carried out on a normalised 0·40 to 0·45% carbon steel, with and without lead addition, under a constant feed of 150 f.p.m., and ⅛ in. feed and depth of cut. The tool wear was measured after the same amount of material had been removed. It was found that the tool used to machine the lead-bearing steel showed no appreciable change, whereas in cutting the non-leaded sample the wear of the tool measured 0·002 in.

As these tests were carried out very carefully, the results afford reasonable evidence of considerable improvement in machinability when lead is added to steels. It will be recognised, however, that metals respond differently to varying machining operations, such as turning, screwing, milling, etc., and further, that in practice machinability is dependent on many factors, such as condition of material being cut, size, cutting speed, shape of cut, coolant, cutting tool and its heat-treatment, and condition and capacity of the machine tool used for cutting in respect of slackness in slides or bearing spindles, etc., and also the individual skill of the operator in charge of the machine. Such variables are responsible for differences in output of a similar article from different machine shops, and even from different machines in the same shop.

Fig. 5.—An assembly of products in free-machining lead-bearing steel.

It will be appreciated, therefore, that while the results of the foregoing machinability tests indicate substantial improvement in machinability when the steel contains a small percentage of lead, it is difficult to lay down hard and fast rules which will apply to all methods employed in machining these steels. Generally speaking, the cooler cutting qualities of lead-bearing steels enable the use of increased feeds for turning, drilling, etc., while the smoother finish, resulting from the better chip formation, allows for increased cutting speeds, thereby coverting increased tool-life into the more useful and advantageous increase of output.

Much depends upon the capacity of the machine tool in making profitable use of the improved machinability of these steels, but where a machine is capable of operating at higher speeds, the speed for Ledloy free-cutting steel may be as high as 400 f.p.m., with feeds for turning and drilling up to 0·015 in. per revolution, for forming up to 0·002 in. per revolution, and for parting off up to 0·0025 in. per revolution. For screwing and tapping, speeds up to 120 f.p.m. may be successfully used. It should be noted that rather steeper angular clearances can be utilised, minimising built-up edge and yielding smoother finishes. The tool angles recommended are: top-rake, up to 25°; side clearance, 3 to 5°; a front clearance, 5 to 8°.

A considerable mass of evidence has accumulated from production tests employing a multiplicity of machining operations under varying conditions, in which the use of lead-bearing steels has increased the output of parts up to as much as 60%. Some examples of work in a lead-bearing free-cutting steel, the output of which has greatly increased since using this steel, are shown in Fig. 5. From the evidence accumulated, a very conservative estimate of the economy effected by the use of these steels, based on the cost of production per article, show cost savings of 5 to 20% on cases so far investigated.

The writer wishes to thank Mr. W. B. Wragge, chief metallurgist of Messrs. the Exors. of James Mills, Ltd., for his courtesy in supplying the results of machinability tests which are incorporated in this article.

Chemistry as an Aid to the Production of Sound Castings

By E. Altenhein, D.Eng., A.M.Inst.B.E.

Materials for removing impurities from non-ferrous casting alloys are discussed. Attention is directed to materials, known as A.M.C., developed as a result of persistent research and experiment, which are claimed to remove impurities. One of these materials has been developed for use with copper alloys and another with aluminium alloys. Some results of tests are given.

THE chemical examination or assay of metal alloys has long been employed as an important expedient in modern foundry practice. Recently, however, chemistry as a means of ensuring the highest quality, has also gained increasing prominence in other directions of equal importance. Up to a short time ago, the cause of faulty castings showing excessive porosity, insufficient physical properties, etc., has mostly been attributed to an incorrect composition of the alloying elements. Today, however, it is known that this assumption can no longer be considered as correct. The metal refiners who are the suppliers of the metals to the foundries make it a rule to-day to carefully check and control their alloys, not only chemically but also mechanically and metallographically. This has become an essential feature in their production programme and only such metals that pass this stringent test are placed on the market. The non-ferrous metal foundries are, therefore, in a position to rely with reasonable certainty on the supply of satisfactory alloys from the refining works, as far as their casting quality is concerned, and with perhaps very few exceptions, it may be stated that the cause of faulty castings, especially if due to porosity, must today be sought for in the foundry itself.

There are, for instance, substances present in every foundry which will have a detrimental influence on the production of a good and dense casting, and which, as for instance, sulphur or oxygen, are present in such quantities that in the event of them being found in the casting, the foundryman need not look for them in the metal he has purchased from the refiners and in which they will scarcely be present.

As the electric melting process has only been introduced in this country to a comparatively small extent, most meltings today take place in crucibles with coke or oil firing, with and sometimes without forced draught. The accompanying factor of these methods of heating is a certain unavoidable air surplus, and it is here where the cause of most faulty castings may be found. In addition to this comes the sulphur contents of the fuel which, during the combustion is converted to SO_2 and which the melter or foundryman knows well by the typical smell it produces. Both oxygen and SO_2 have the tendency to combine with the melting metal in the crucible. Unfortunately, however, this absorption or solution of the gases takes place in such a manner that later, during the process of solidification in the mould, these gases will again be expelled due to the variation in the solubility of the metal for these gases at different temperatures, and it is mostly this subsequent escape of gas from the metal which is respodsible for the porosity found in the casting.

The absorbent properties of the metal for sulphur, oxygen and other gases, therefore, reach a maximum at a time when the metal is in the fluid state and is being prepared for the cast. It is under the observation of this circumstance that tests have been first made in order to find the best suitable means for avoiding this condition. The covering of the metal with charcoal to keep the oxygen of the combustion air away from the metal is as old a method as the melting of the metal itself. As, however, the danger of gas absorption is greatest during the beginning of the melting, a noticeable success can only then be achieved by this process after a complete melting of the metal has already taken place as it is practically impossible to efficiently cover the solid metal blocks with charcoal before they have been melted down or at least submerged in liquid metal. Before, therefore, this primitive method becomes effective, the metal itself can have become impurified to a considerable extent. In addition to this, it must be considered that the charcoal would tend to burn away very rapidly, thereby rendering it ineffective after a short period. A further unfavourable factor also arises when using this material. Charcoal has not only the property of combining oxygen, but it also absorbs other gases which may be present. This fact may be well responsible for the bad results which have been obtained in spite of the liberal use of charcoal as compared with tests made without this material. For instance, in the event of the combustion gases being rich in sulphur, the SO_2 will be absorbed by the charcoal layer and would then be brought in direct contact with the liquid metal during the stirring process. By this, the direct opposite would be achieved of what has been aimed at, as the affinity of the metal for sulphur is higher than that of charcoal and the sulphur would, therefore, wander into the melt to a greater degree than if no charcoal had been used.

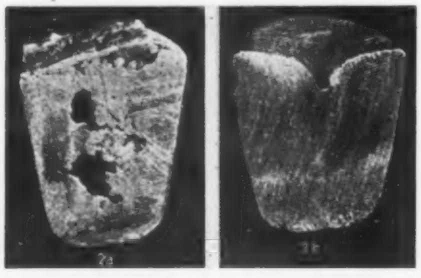
In consideration of these adverse conditions, a number of extensive tests have been recently carried out in order to remove the accompanying disadvantages, and two distinct groupes of materials were developed, both of which, however, have so far not succeeded in getting to the root of the trouble.

The first of these materials was principally concerned with the removal of disturbing impurities in the form of other metals and is, therefore, based on the generally incorrect assumption mentioned above, that faulty castings are due to the disturbing presence of foreign and undesirable metals. Materials of this kind, therefore, work on the principal of removing these foreign metals by oxidation, inasmuch as they are distinguishable from the basic metal constituents by a higher affinity to oxygen. As simple as this may appear, it unfortunately does not avoid the simultaneous oxidation and removal of the other very important alloying components, such as zinc and tin whereas on the other hand, unoxidised rests of the metals which were to be removed, still remain in the melt. An undesired change in the analysis is, therefore, generally the result of this procedure. Furthermore, it is in many cases very difficult to remove the surplus oxygen and oxides introduced by this process. From a theoretical as well as a technical aspect, such materials are, therefore, to be avoided with perhaps the exception of special cases, where their use is justified by the required analysis or composition of the melt.

The second series of materials, with which an attempt was made to overcome the difficulty consisted, on the other hand of suitably composed covering preparations. No matter, however, how good the covering properties of these compounds may be, it will frequently occur that the molten metal will have already absorbed a certain proportion

of gas before the covering material has been able to operate to its full efficiency. The success is, therefore, often only a limited one, as even if the covering material is of the very best quality and composition for its specific purpose, the oxygen and sulphur already absorbed by the metal will not be extracted by its use, and will, therefore, remain in the melt as impurities.

Guided by the experience gained with the above mentioned materials, long and extensive tests have been made, assisted by scientific research with the object of finding a material that will fulfil its required purposes in every direction without entailing the accompanying advantages. It was soon realised that this could only be achieved with the help of a multiple acting compound, and the recognition of this fact was the first step to the solution of a problem of unquestionable importance for the metal industry. Progress was naturally slow at first, and it was only after the results of numerous experiments by recognised laboratories had been completed, that the chemical industry was in a position to present the metal founder with a new and important expedient which can be successfully employed in removing the manifold sources of faults during the production of high-quality castings.



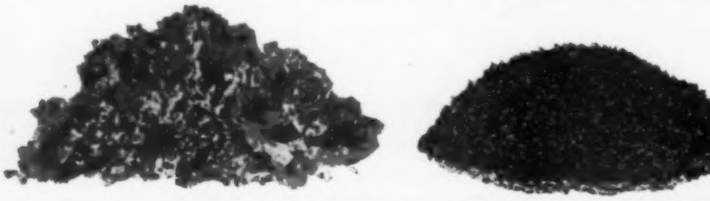
Figs. 2a and 2b.—Aluminium ingots cast without and with a flux.

The principal advantage of this new material is that it is neither an ordinary covering material nor a material which will incur an alteration to the analysis of the melt by its oxidising influence. It is a multiple acting product which combines the advantages of previous individual fluxes, and adds to them other essential properties. This product, which is manufactured in England and is known under the title A.M.C., distinguishes itself primarily by a very low melting point. It melts already when the metal charged becomes red hot, and covers the still solid charge with a thin protective coating, and, if applied correctly, it avoids completely the absorption of gases, irrespective of their nature. During the melting process, these materials develop neutral and reducing gases which establish a certain gas pressure above the surface of the metal, thus avoiding the entrance of combustion gases or air into the crucibles.

Furthermore, the oxygen and sulphur which may be present in the metal are removed by chemical reactions and transferred completely to the slag. In addition, these materials prevent the formation of a slag rich in metal, whereby the loss by oxidation, which plays a prominent part in the economics of a process as well as being the cause of frequent disturbances due to an alteration in the analysis of the melt, will be practically eliminated.

The development of a multiple acting material of this nature encountered, of course, numerous difficulties, which, however, it was possible to overcome. Special endeavours were made to find a material which was simple in use and did not compel the foundry to keep different preparations in stock for every type of casting. The solution to this problem was found in the restriction to only two materials, these being one preparation which was suitable for all copper alloys such as, brass, bronze, gun metal, german silver, Monel metal, etc., and the second preparation made specially for aluminium and all aluminium alloys.

The latter material distinguishes itself, above all, by the fact that the principal cause of most faulty aluminium castings, i.e., the hydrogen content of the metal, is completely absorbed and removed by the use of this flux. At high temperatures at which the aluminium is in the molten state, the hydrogen is retained in the metal in the form of a solution, but when the temperature drops, as for instance during the solidification of the metal in the mould, the hydrogen is again released as a gas and causes the porosity which it is so difficult to avoid. Only by a complete removal of the hydrogen at the higher temperature is it, therefore, possible to avoid this occurence. It is, of course, conceivable that porosity in any form, and even to the minutest extent, will have a definite influence on the physical properties of the ultimate casting, a fact which explains immediately the noticeable increase in the tensile properties of the castings treated with this new flux. One or two tests extracted from a series of experiments carried out by official research laboratories are quoted in the following, from which the influence of this new material on the porosity can be seen. In each case, the metal was tested for its gas content by means of the Straube-Preiffer apparatus, which creates a vacuum above the liquid metal and enables



Figs. 3 and 4.—Showing the slag from an aluminium melt without and with a flux.

the observer to see immediately whether an escape of gas from the metal takes place.

Fig. 2a shows a section of an aluminium casting produced from aluminium ingots, which were melted in the crucible without the use of a flux. When this crucible was placed in the testing apparatus at a temperature of 700° C, the metal surface was agitated and bubbles rose to the surface. This indicated the presence of gas. After solidification, the casting was sawn down the centre, and the illustration shows clearly the porosity which was present.

The result of the counter-test is shown by Fig. 2b. When this counter-test took place, the crucible was charged with the same ingot material, but it was melted down with a slight addition of A.M.C. aluminium flux. After melting was completed, the slag was removed, and by means of a further small quantity of aluminium flux, the melt was degasified. After the temperature had dropped to 700° C, the crucible was placed into the testing apparatus. The surface of the melt remained perfectly calm, which indicated freedom from gas. The complete absence of gas was established by the section of the solidified metal. The cut itself shows distinctly a perfectly smooth surface and a clearly defined pipe.

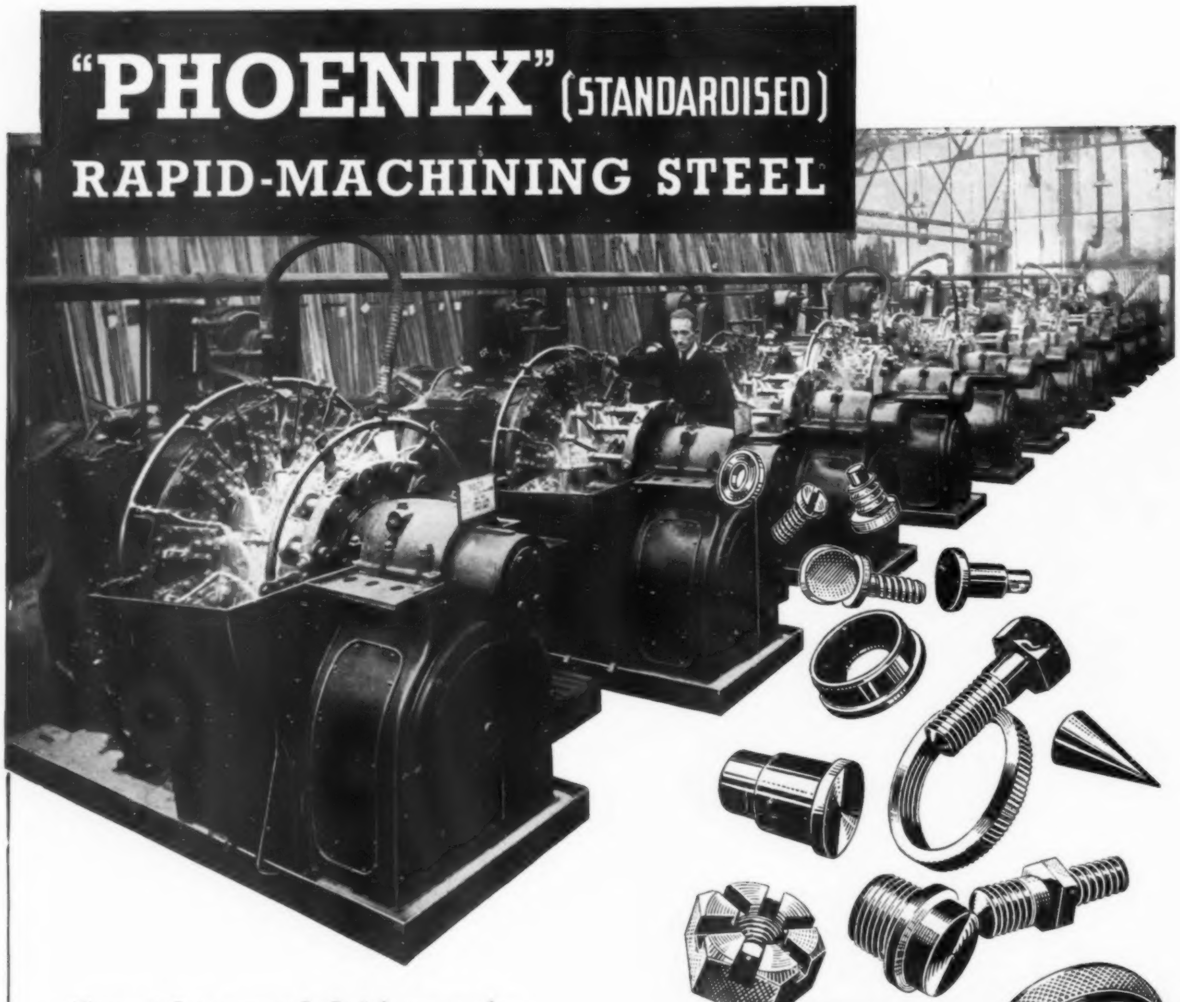
Figs. 3 and 4 show that the use of a suitable flux means a considerable saving in metal. Fig. 3 shows the slag removed from an aluminium melt which has not been treated with a flux. This slag is spongy and irregular and contains a high percentage of metal. Fig. 4 shows the slag removed after having been treated with A.M.C. flux. The slag is dry and powdery and low in metal content.

On the ocassion of the last international Foundry Congress in Warsaw, Professor Dr. J. Czochralski and Engineer K. Migurska presented a paper giving the results of numerous comparative tests with various fluxes. These investigations showed that the material mentioned was the only one with which the porosity figure of 0 and, at the same time, the most favourable physical properties of the metal, as well as the highest specific gravity, were attained. This result was obtained without the slightest difficulty and without incurring any alterations in the melting or casting equipment nor to the standard casting practice.

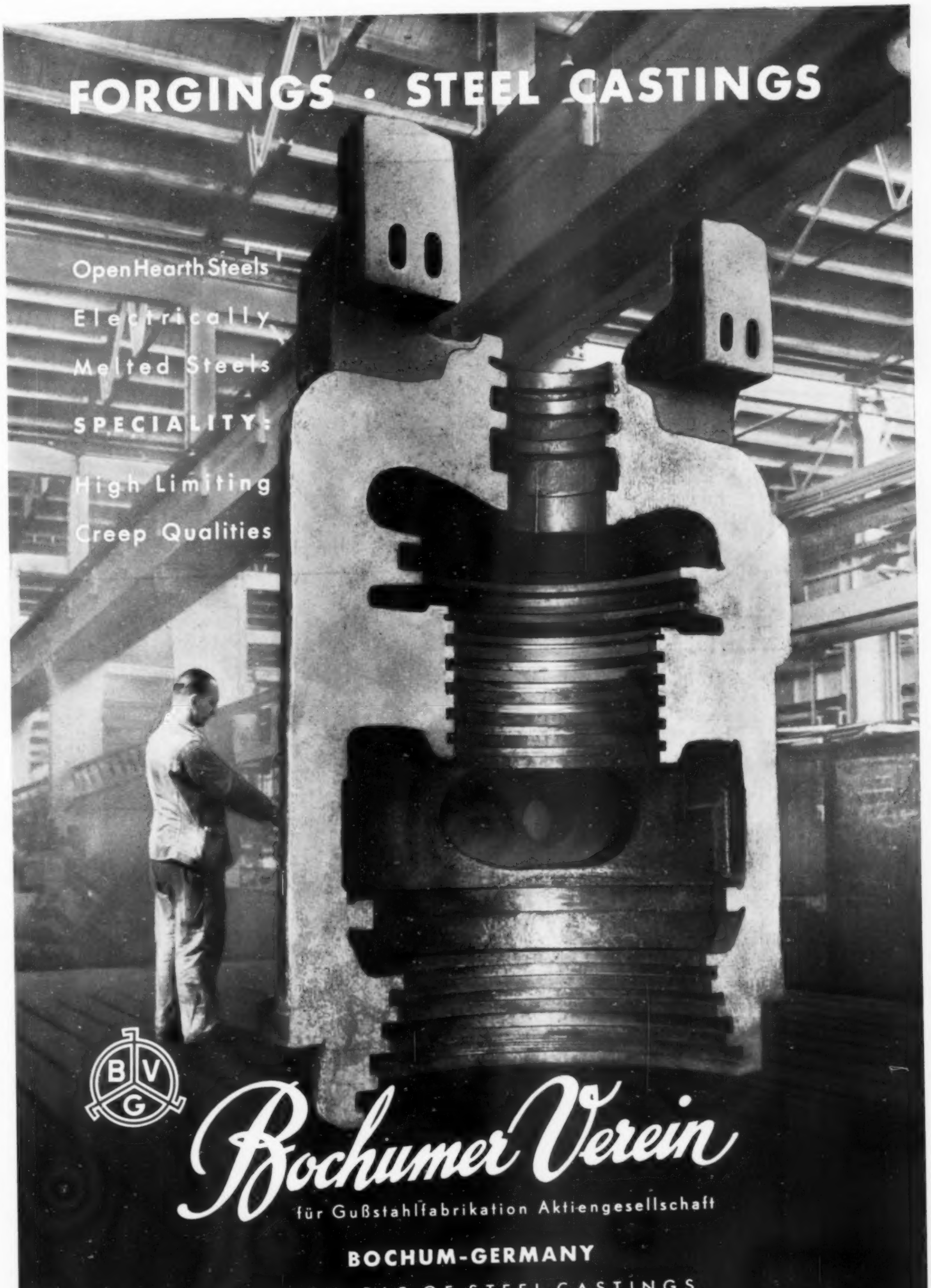
STEEL

ITS USES IN THE MAIN INDUSTRIES

July, 1939 METALLURGIA Vol. XX. No. 117



"PHOENIX" (STANDARDISED)
RAPID-MACHINING STEEL
For perfect smooth finish up to the highest speeds of which modern machines and tools are capable; "Phoenix" [Standardised] Rapid-Machining Steel is consistent in composition and its machinability "always the same."
Write for the "Phoenix" Book Ref. No. SPT. 205 to :—
THE UNITED STEEL COMPANIES LTD
STEEL, PEECH & TOZER
Branch of The United Steel Companies Limited
SHEFFIELD
Telephone: Sheffield 41011 Rotherham 1090
Telegrams: "Phoenix" Sheffield
PH.23


FORGINGS · STEEL CASTINGS
Open Hearth Steels
Electrically
Melted Steels
SPECIALITY:
High Limiting
Creep Qualities
BVG
Bochumer Verein
für Gußstahlfabrikation Aktiengesellschaft
BOCHUM-GERMANY
THE CRADLE OF STEEL CASTINGS

MASS PRO

2-ton Electric
Arc Furnace.

Machine-Moulding
bay.

STEEL

By

Mr. W. J. BROKE, J.P.

Joint Managing Director,
Messrs. John Lysaght Ltd., Scunthorpe

The use of steel is closely associated with the progress of mankind. In a relatively few years, by man's endeavour, it has reshaped the whole fabric of civilisation.

WE are living in an age which is witness to the efforts of science to produce substitutes for old-established products, or alternatively for the synthetical production of various materials. It is true, many and various attempts have been, and are still being made to produce substitutes for steel, and a number of instances have proved satisfactory as in the case of ferro-concrete which, while replacing steel in the bulk, still has to rely upon it for its most important function. The uses to which steel can be put are growing daily, and strong efforts are continually being made by the Industry to foster their growth. We in this country, however, still lag somewhat behind other parts of the world in applying it, notably the U.S.A.

Many of us are apt to look upon the consumption of steel only in terms of bulk consumption, such as ship-building, railways, modern steel-frame buildings of large size and construction work generally. We have also, within the last twenty years seen the enormous growth of the motor-car industry, which has reached its present state largely through the substitution of wood and other materials by steel for the construction of the bodies. In this respect, steel has played a very great part, and the resources and ingenuity of steel makers have been taxed to the utmost so as to enable the press shop to produce complicated shapes in a wide range of sizes. Heavy demands for high-grade steel in sheet form, required by the motor manufacturers have caused some steel makers to install continuous strip mills for the rapid and economic production of such material, with the result that, owing to the greater availability of such material, it has been applied to an enormous number of purposes where wood or other materials had previously been used. It is difficult to realise that sitting in the coaches of some of the de luxe American express trains one is encased almost entirely with steel; panelling, window frames, doors, furniture, everything that one can see is steel, and so cunning is the manner of its adaptation that until one raps on it with one's knuckles, it is almost impossible to realise that it is not the wood that we have been accustomed to see in this country. It is true that steel has been largely used in the construction of some railway carriages now operating in this country, but the use of wood predominates; gradually, however, we may see a change in the choice of material and a preference given to steel, which would add considerably to its extended use.

Whilst thinking in terms of mass consumption, one must not get away from the fact that there is the possibility for the usage of steel in an almost inconceivably large number of directions for objects comparatively small in themselves. One is quite astonished to hear of the considerable tonnage of steel that is used up year by year, in forming the caps for safety pins. The stoppering of bottles by means of steel instead of cork or other material, is also accountable for the use of a large quantity of steel, and there are thousands and thousands of other cases of a similar nature which, when added together, create a total which is by no means inconsiderable. During the past year, for instance, granulated steel has been mixed with cement to provide a hard-wearing surface covering. The thickness of the covering varies somewhat, but usually does not exceed ½ in. The amount of steel used is only about 4 lb. per sq. yd., but during the year well over a million sq. yd. have been applied. It is in many directions such as these where the accumulative effect of apparently small applications of steel makes an increasing demand upon manufacturers.

When one considers the realms of higher-grade material, the extent to which alloy steels have already effected a revolution in practically all present-day activities will be appreciated. Indeed, it is doubtful whether there is a single industry or branch of commerce which has failed to benefit directly or indirectly from their use. Consider the marvellous results now being achieved by the use of stainless steel, and the many and varied uses to which alloy steels of various types can be put; they have contributed in a large measure to the raising of the various engineering industries to a new level of achievement.

The continuance of the systematic application of science and technology which has characterised the iron and steel industry for the past fifty years will lead to further metallurgical and economic developments which will further enhance the application of steel. Even now, when the industry is making strenuous efforts in its contribution to the rearmament and defence programme, new avenues are being explored, with a view to the application of steel, so that when the national programme nears fulfilment, the high-production capacity of our present steel plants may be used to supply increasing steel requirements for normal peace-time purposes.

All-steel mono-piece chassisless motor car bodies on assembly conveyer line.

Courtesy of Pressed Steel Co., Ltd.

The Manifold Uses of Steel

By W. H. HATFIELD, D.Met., F.R.S.

Various alloys have increased the usefulness of steel and enabled man to reach pinnacles of achievement in construction and service which were undreamed of only a little while ago.

THE manifold uses of steel for bridges, steel-framed buildings, rails, motor-car bodies, screws, nails and wire is one of the features of this age; and although the vast quantities of steel used for such purposes as carpenters' nails is often not realised, the essential basis of steel in our civilisation to-day, is generally inderstood. All such bulk production of ordinary steel may, however, be classed as "common steel," and from a technological viewpoint it differs little from the metal iron.

There are, however, many engineering requirements which cannot be met by ordinary steel, and metallurgists have been faced with the problem of modifying the fundamental properties of the metal iron to fit it more closely for particular conditions of service. It is this aspect of steel production—relatively small in total tonnage, but immensely important in our industrial structure—to which the writer wishes to direct attention.

The efficient use of fuel to provide energy for the production of electricity or the propulsion of ships, involves the use of high-pressure, superheated steam, and the consequent demands made upon metallurgists in providing suitable materials, aptly illustrates the difference between common steel and special steel. In modern, superheated steam practice, steam temperatures run as high as 500° C., and it is not difficult to imagine the severity of the stresses imposed upon a turbine rotor which is revolving at a peripheral speed of the same order as that of the earth at the equator. The matter is, however, considerably aggravated by the fact that metals at such temperatures cease to be wholly elastic substances, and are subject to "creep," under the effect of sustained loading. The normal life of a steam turbine is not far short of 20 years, and since clearances have to be maintained within a few thousandths of an inch, the permissible rate of "creep," under load at the operating temperature, lies somewhere between 10^{-8} 10^{-9} inch/inch/hour. The resistance of ordinary steel to such "creep" is improved by alloying with the metal, a small quantity of the element molybdenum, although such an addition introduces problems of a technical nature in regard to manufacture and thermal treatment of the forging prior to machining.

In the case of the rotor, the problem is to obtain sufficient strength to withstand the stresses imposed in service at the operating temperature, but in the blades the matter is severely complicated by the erosive and corrosive action of superheated steam. For moderate superheat stainless steel and stainless iron containing 13% of chromium are used, and such materials are eminently satisfactory from the triple standpoints of strength, resistance to wear and resistance to corrosion. When really high superheat in the order of 500° C. is employed, however, it is necessary to employ a steel which possesses a higher "creep" strength than the ordinary martensitic and ferritic steels already described and for this purpose several different compositions of austenitic steel containing high contents of chromium and nickel are in general use.

In the above considerations, three or four salient properties of metals have been touched upon, namely strength at ordinary temperatures, strength at elevated temperatures, resistance to erosion and resistance to corrosion; but electrical generating machinery also offers an interesting example of another important feature.

It is generally assumed that iron—and steel—are magnetic. Indeed, the term ferromagnetism implies that this is so; but in response to the demand for a metal for alternator retaining rings, which was as strong as steel but non-magnetic, metallurgists some years ago introduced a steel which was non-magnetic.

This interesting material is also characterised by possessing an abnormally high coefficient of expansion almost equal to that of aluminium alloys, and has found important application for aero engine valve-seats and for cylinder holding-down studs and crankcase bolts.

Now the development of such materials has gone even further, and a stainless steel which is absolutely non-magnetic, even when cold-worked to spring temper, has been devised.

The problem of wear-resistance is one which has produced a wide variety of alloy steels to meet different conditions of service. Increasing the carbon content of mild steel improves its wear-resistance, and alloying the element chromium in amounts up to 1% or more, also improves resistance to abrasion. This type of steel reaches its optimum properties in the glass-hard ball-race type of steel.

Such steels, although hard, tend to be brittle; but advantage may be taken of the hardening effect of carbon, whilst retaining a tough core, in the case-carburising process. The properties of the core may be further improved by alloying nickel and chromium. One of the major disadvantages of the case-hardening process is the fact that the part must be quenched in water or oil from a red heat with consequent risk of distortion; but this risk may be overcome in great measure by hardening steels of special composition in ammonia gas at 500° C. Great intrinsic hardness exceeding 1,000 diamond, or lower hardness with greater toughness may be obtained by controlling the relative content of the elements, chromium and molybdenum. Aluminium is also an essential constituent of the hardest grade.

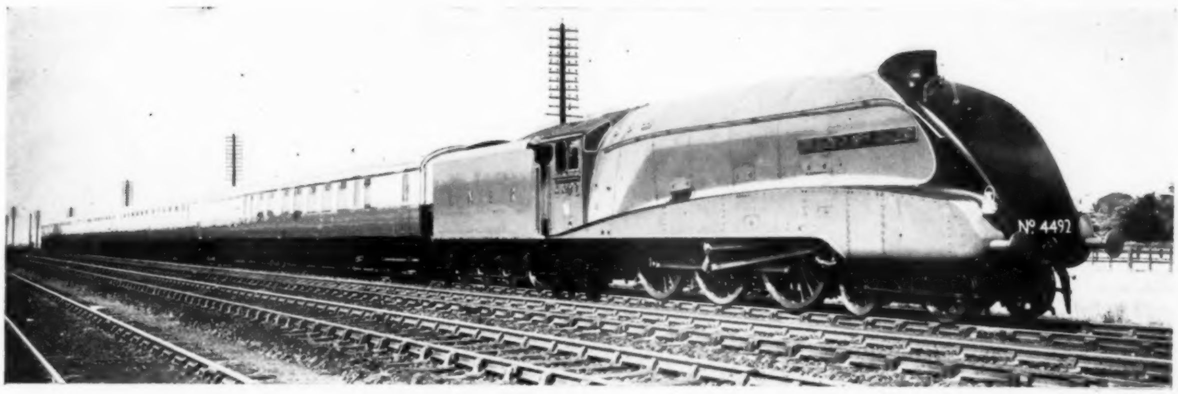
Huge plants for the production of industrial nitric acid and other chemicals are constructed with the aid of 18-chromium, 8-nickel, acid-resisting steels. These steels are employed in the dyeing and pharmaceutical industries. They are used for the construction of dairy and brewery equipment and of plant for the production of foodstuffs. They are used for domestic and architectural purposes, in hospitals and aboard ship.

Heat-resisting steels which will not scale unduly at 1,100° C., and steels many times stronger at red heat than common mild steel, are employed in furnace construction, and in aero engines for valves and exhaust manifolds. They are used in oil-cracking plant and for superheater supports.

Reference must also be made to the place of alloy steels and ferrous metals in modern production.

Since the day when high-speed tool steel first permitted engineers to run their cutting machines at a rate which would have softened and wrecked ordinary carbon steel tools in a few minutes, metallurgists have been contributing improved materials for tools and dies in response to an ever-present demand for improved performance. Most recent is the development of the special hard sintered carbide tools which combine toughness with intense hardness. When first developed, carbide tools were hard but brittle; but now considerable advances have been made towards meeting the requirements of tools subjected to rough and intermittent cutting in addition to plain, high-speed continuous machining.

In the space of this review it has been possible to enumerate only a fraction of the numerous functions performed by special steel; but if the writer has succeeded in showing how modern ferrous technology and development in all fields of power engineering and many fields of industrial production are interdependent and complementary, then he will have done something towards indicating the place of steel in our everyday existence.



The front portion of The Coronation Express of the London and North-Eastern Railway Company.

Steels used by the British Railways

By T. H. Turner

CHIEF CHEMIST AND METALLURGIST, LONDON AND NORTH-EASTERN RAILWAY

"The iron backbone of the country's commercial economy," was the picturesque description of the railways, recently used by the Minister of Transport. The description was, moreover, literally true and amply justified by the varied and widespread use of iron and steel in railway track, vehicles, ships and ancillary services.

RAILWAYS were the first important users of iron and steel to provide a regular and large demand for standardised products of the iron and steel industry. This may be confirmed most easily by referring to the dates of British Standard Specifications, which show that the earliest efforts towards agreement between supplier and user as to standardisation of requirements was in connection with iron and steel for railway purposes.

In many respects, the railways have become better customers of the various sections of the iron and steel industry. They have spent no less than £350,000,000 on major renewals, reconstructions and replacements during the past sixteen years and the increase in frequency, weight and speed of traffic has required increase in the weight of iron and steel in the track and vehicles. The railways of Great Britain alone purchase upwards of a quarter of a million tons of rails each year. Rails have become heavier in sections and longer. The 95 lb./yard section, bull-head rail in 60 ft. lengths has been most widely used in this country.

It is not easy to picture the great weight of iron and steel absorbed in this country's railway tracks, for there are 250 tons of iron and steel in a mile of single main line track alone, and as much as 10,000 tons of these metals in the complicated system of multiple tracks, bridges and signalling, in the first mile of railway out of one of London's terminal stations. Including sidings, there are 50,593 miles of railway tracks.

A generation or more ago, rails varied greatly in composition and they were purchased on the Continent and from countries as far away as Russia and the U.S.A., as well as being made to some extent by the railways themselves. Present-day requirements are more uniform and are met entirely by a dozen or so makers in Great Britain.

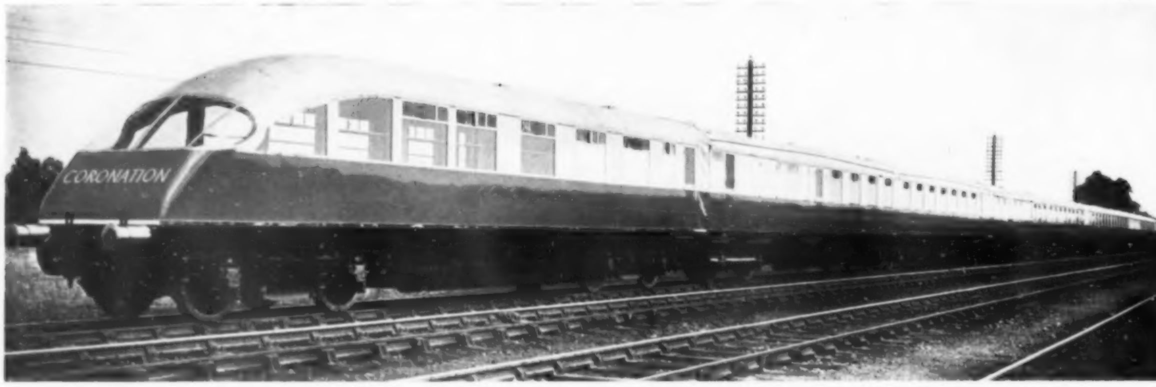
The medium manganese rail most widely used, with 0.56% carbon and 1.0% manganese, has a very fine pearlitic structure under normal cooling and the same work-hardening characteristics as the best of the older rails, 1% of chromium has also been added in many tons of rails laid experimentally, but the opinion has been expressed recently by a main line railway metallurgist, that the use of alloy additions to rails could not be regarded as economical until the best had been brought out of the cheaper compositions by properly controlled heat-treatment.

Full use is not yet being made of the controlled accelerated cooling of rail heads pioneered by the Sandberg brothers, but many more makers are now equipped with the apparatus for carrying out this process. By dropping the carbon content and increasing the severity of the controlled cooling, a harder wearing head and a tougher foot will be obtained in future rails. Martensite will be found in the microstructure of these improved rails. At present, rails with Sandberg hardened heads are becoming almost the standard in the southern part of England and elsewhere where traffic conditions are particularly severe.

At least one railway also requires the heat-treatment of fishplates, but there is scope for real improvement in the honestly-controlled heat treatment of almost all the sundries used by the railway engineers, fishplates, nuts, bolts, spikes, screws, and gangers' tools, to mention only the more obvious. At present, the heat-treatment of these articles is generally not specified.

Other countries have been quicker to experiment with various methods of butt-welding of rails and there have been many noteworthy developments with the flash-butt, thermit, Boutet and other processes. The L.P.T.B. Railway Engineers installed two electric flash-butt welding machines a year or more ago, and have been joining together as many as five of the usual 60 ft. lengths before transporting the long length of butt-welded rail to the site for laying in the track.

Other British railway engineers have been shy of the butt welding of rails because they value the ease of replacement of the 60 ft., bull-head rail. The long, welded lengths abroad have been with flat-bottomed rail of possibly greater lateral rigidity than is possible with bull-head track held by keys. The probability is, however, that much use will be made of rails received from the mills in normal lengths, with hardened heads, and subsequently



The rear end of The Coronation Express of the London and North-Eastern Railway Company.

flash-butt welded into lengths of a hundred yards or more.

Building up of worn points and crossings by welding is now an established practice, for which the oxy-acetylene process is generally preferred, although electric welding plant has been in frequent use for this purpose.

Corrosion plays little part in the life of rails laid in country districts, but it is the cause of the shortening of the life of rails in tunnels to as little as three years in some cases. The protection of the foot of the rail against corrosion is a matter requiring attention in such circumstances.

Railway engineers have been responsible for some very advanced uses of welded constructions for bridge work and any low-alloy steels suggested for this type of work will need to be safe welding materials in the future. Parallel with the use of welded steel in bridge-work, much ferro-concrete is to be noted in new railway work and that has required the consumption of many tons of steel as re-inforcement members.

Forty or more types of galvanised and bare wires and cables used mainly in fencing and signalling present another important outlet for steel in railway engineering, for there are no less than 10,297 signal boxes.

The heart of the locomotive, the boiler, still uses mild steel for plates and tubes in the great majority of cases, but the L.M.S. Railway have made many recent locomotives with 2% nickel steel boilers, and low-alloy steels are being tried for frames. The more expensive modern locomotives have nickel-chromium - molybdenum alloy steel connecting rods Fireboxes and stays are generally still made of copper, except on the Southern Railway, where Monel Metal stays are now standard on some classes of engines.

Widespread introduction of feed water treatment and higher boiler pressures may so change the conditions in the boiler that steel fireboxes and stays may be introduced, but such a move will only come after due experiment. Steel fireboxes, with steel tubes welded in, are, however, widely used in the U.S.A., and may be seen in the smaller British boilers when all feed waters are adequately softened. Where the lime-soda-sodium aluminate system of softening has been fully adopted, corrosion has been much decreased or entirely eliminated. Such corrosion of locomotive tubes as has been reported recently is associated with intreated acid or incompletely softened feed waters.

Hundreds of tons of higher-carbon steels are used each year in railway wheels, tyres, axles and springs.

Many carriages and wagons have mild steel underframes although some experiments have been made with several low-alloy steels. The use of these newer types of steels with enhanced corrosion resistance has progressed further in the U.S.A. than in this country. Experiments are being made with several compositions, however, and some difficulty has been experienced with the welding of them.

Carriages and wagons are nowadays frequently made from steel as regards the underframe and bogies, and all components below the frame such as tyres, wheels, axles, springs and brake gear. There is still a wide use of wood for wagon floors, sides and roofs, and in some carriage sides and roofs. The tendency continues to be in the direction of using more steel and less wood, and welding is used in carriage and wagon construction more than ever before. The lightening of steel constructions made possible by welding have opened up the possibility of replacing wood by steel without increase in overall weight and this possibility is under constant review by designers of railway rolling stock.

The junction at the East End of the Central Station, Newcastle-on-Tyne, one of the most important junctions on the London and North-Eastern System, comprising 92 manganese steel crossings weighing over 70 tons.

Courtesy of Hadfields Ltd.

Tinplate and the Canning Industry

By W. E. Hoare, B.Sc.
International Tin Research and Development Council

The manufacture of tin cans and metal boxes constitutes a major outlet for steel; thus the packaging industry forms an interesting link between the steel trade and food production. Here the author refers briefly to developments in the tinplate industry and to can manufacture.

PRESERVING and safeguarding commodities during transport and storage is a vital necessity to modern civilisation, particularly in the case of foodstuffs. In supplying a complete answer to this need, the canning industry has established itself as an indispensable service at all times, and, in addition, it provides a means of carrying crops from times of glut to times of scarcity and may provide an invaluable reserve of nourishment in crises.

It is natural that interest in a can of food should lie chiefly in its contents, but it is worthy of thought that the manufacture of tin cans and metal boxes constitutes a major outlet for steel. The packaging industry thus forms an interesting link between the steel trade and food production. In 1937, for example, nearly twice as much steel was used in the manufacture of tinplate and terne plate as was used for the manufacture of rails. Certainly over 60% of this production was used in the manufacture of containers and closures.

The Tinplate Industry

Recent years have seen the tinplate industry in a most interesting stage of development. The traditional "pack-rolling" method of manufacture had held its own without question for 200 years until less than twenty years ago, when the continuous cold-reduction process appeared. During the few years since its inception this method has caused as great a revolution of ideas in the industry as did the invention of the Siemens and Bessemer processes fifty years ago.

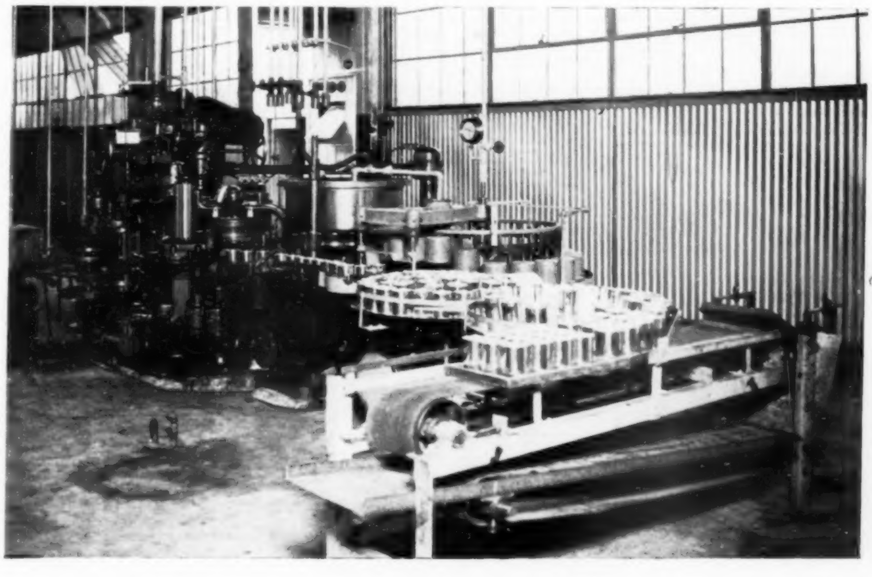
The continuous cold-reduction process has two essential features which distinguish it in principle from the "hot-pack" method. The steel is rolled in a continuous ribbon or strip and is not cut into sheets until immediately prior to the tinning operations. The process also involves a considerable and significant amount of cold-reduction. Although the relative merits of the two processes could be, and have been, discussed at length, the position may be summed briefly as follows: The advantages of the hot-pack method are low capital cost of plant and considerable flexibility, of output; while the continuous process gives an improved product and lower labour charges. But against the advantages of the newer method, it is necessary to consider the high capital expenditure, a certain lack of flexibility consequent upon the high degree of integration, and the necessity to work the plant at something close to capacity. This last factor may, under adverse conditions, off-set the saving in labour.

The merits and demerits have, however, been carefully weighed and the balance has come down heavily in favour of the newer method. In the United States at the end of 1938 the productive capacity for cold reduced tin mill products amounted to 2,368,000 tons annually, or 55% of total. The Ebbw Vale plant of Messrs. Richard Thomas & Co., completed this year, represents the first installation of the type in this country. Other mills are under construction in this and in other countries.

The abruptness of a change-over from manually operated 2-high pack rolling mills to complete continuous hot and cold reduction, with a total of from 14 to 20 four-high mill stands and their ancillary equipment, may be lessened by several possible intermediate arrangements. Considerable improvement is secured by mechanisation of existing mills; the use of continuous hot-mill break-downs in pack-rolling plants may secure certain advantages common to both processes; the single stand reversing cold mills and hot mills may provide an answer to the need for plant with the technological advantages of the cold-reduction method combined with smaller capital outlay.

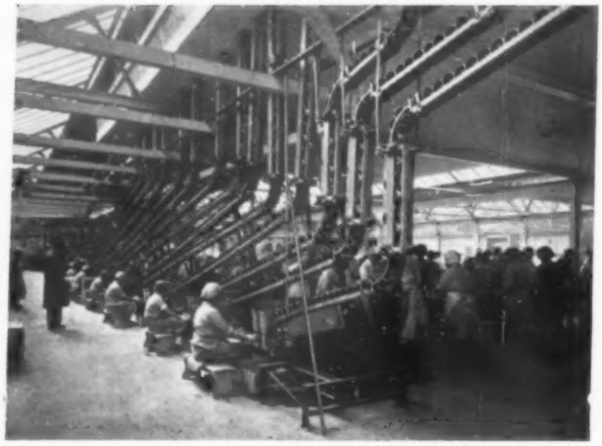
Tinning

Although numerous improvements in tinning machines and tinning pots have resulted in better control and faster working, the basic principles have shown little change as compared with the radical alterations in the procedure of manufacture of the basis material. Apart from narrow-width stock, the difficulties of continuous strip hot-tinning on a commercial scale have not, so far, been overcome.



Courtesy of Hawaiian Pineapple Co., U.S.A.

This machine, used for canning pineapple, first breaks down the air cells in the pineapple, which allows the syrup to permeate through the fruit. The cans then go to the vacuum seamer, where they are sealed cold under vacuum. The "Dole" cannery is the only pineapple cannery that vacuum packs its products in this manner.



Courtesy of Foster Clark & Co.

Delivery of fruit from inspection belts (right) into cans, without being handled.

The availability of coiled strip has naturally stimulated research into these problems, and there is every reason to believe that tinned strip in wide widths will in time become available. It is of interest to note recent reports in the technical press of the progress in this direction by the Crucible Steel Co., of Pittsburg, U.S.A.

Can Manufacture

Although tinplate is used for a variety of those purposes where a light, soft, sheet-metal is required, its major field of consumption is in the form of cans, metal boxes and closures. An idea of the size of this field may be gathered from the fact that in 1935, the United States alone produced over ten thousand million packers' cans. In this country, the canning industry has made spectacular strides during the past decade, and in one single factory production may amount to over half-a-million cans a day. Packers' "open-top" cans are now produced entirely by automatic machinery. General line containers, although lending themselves less readily to mass production methods by reason of their variety of shape and size, are turned out at speeds which compare very favourably with the 300 per minute output of the open-top can-making line, which may be taken as the typical example of contemporary can-making methods.

The can-making plant actually consists of a number of automatic machines connected together by conveyers.

This shows the "Exhaust" process in which removal of most of the air from the can and contents is achieved by heating before the lids are sealed on. The cover has been temporarily removed from this "exhaust" box, and the cans are shown half-immersed in hot water. They stand on slowly rotating plates which transfer them along spiral paths from the inlet to the outlet, which they reach after a few minutes.

Courtesy of International Tin Research and Development Council

A trimmer cuts the tinplate to size and stamps out a notched body blank which is passed to the forming mechanism. Here the flat blank is folded at the short edges to form the seam, rolled up into cylindrical shape and the seam locked, closed and soldered. At the next station, both ends are bent out on a flanger ready to receive the bottom end and closure. A double seamer closes on the bottom and the finished can passes immediately to a machine which tests for leaks and automatically rejects unsatisfactory cans. The ends and closures are made on a separate line consisting of a scroll-shear, press and seam curler. The gasket compound, which ensures the necessary air-tight seal, is applied in liquid form by spraying from a fine jet and dried off in a continuous oven.

Decoration, varnishing and lacquering are practically always carried out previous to fabrication of the can or box. Although certain protective coatings, such as those used for beer cans, may be sprayed on after the can is finished, the large majority of lacquer and varnish finishes are applied by roller coating machines followed by continuous or batch-type drying ovens. Decoration by printing is usually done on single colour rotary off-set presses, but a small number of two-colour machines are now in use for tinplate.

The Canning Process

Aside from the preparation of the food before placing in the container, the operations of canning may be summarised as filling, exhausting, closing and processing. In a typical case, solid fruit or vegetables are packed into the previously sterilised open-top can either from feed hoppers or by hand. Fruit and vegetables are usually packed in a syrup or liquor, and this is injected by an automatic valve which fills the cans to a predetermined level.

The next step in the process is the exhausting or vacuumising operation. Air or gas left in the can may cause trouble in processing and early deterioration of the pack, and it is therefore essential that the filled cans shall be efficiently exhausted of air prior to the hermetic seal. This may be done either thermally or by sealing the cans under vacuum. The latter method is mainly used for meats and non-food packs, although certain fruit packers have found it advantageous. The thermal exhauster consists essentially of a tank containing hot water with conveyors for circulating the filled cans. The double seamer for sealing the closures on to the exhausted cans is placed very close to the exit of the exhauster in order that air-intake shall be reduced to a nimimum. In some cases the closures may be loosely attached to the can prior to exhausting, with the object of securing a reduction in the interval between exit from the exhauster and arrival at the double seaming operation. In the processing operation which follows, the filled and sealed cans are heated to a temperature of about 100° C. The exact time and temperature of processing depends on the variety and type of food. After processing the cans are cooled, sometimes under pressure, and are then ready for labelling, casing and shipment.

Although the development of canning has been marked with such conspicuous success the industry is not content to rest on its laurels. Canning interests have always been eager to initiate and prosecute schemes of research and development with the aim of improving and extending the range, variety, purity and attractiveness of their products. Canned commodities now range from complete meals to tennis balls. Beer-canning has made enormous strides in the U.S., and already in this country accounts for a significant consumption of tinplate. The possibilities of packing special foods and beverages having desirable medicinal or nutritive values have not been overlooked.

The days of retail selling from scoop and bin are surely disappearing, to be replaced, advantageously it is thought, by the branded package of guaranteed weight, purity and quality.

Steels in the Automobile and Aeronautical Industries

By W. H. Hatfield, D.Met., F.R.S.

The development of the automobile and later the aeronautical industries to their present state of efficiency is largely due to improvements in quality and range of steels to meet the particular demands of these industries. The uses of steels in these different branches of engineering are briefly considered.

ROAD and motor transport by means of vehicles in which the engine unit is an internal combustion engine has made steady progress over the last twenty years, and for some time now has reached such a stage as to vie in importance with the older method of transport by rail. The development of transport by air has been of a more meteoric nature, and has received special fillip more recently by reason of special national demands.

The automobile and aero industries have very much in common, and each has contributed technical data from which the other has been able to profit. Considering the application of steels to special industries, it is natural to couple these two industries together, and in the present article a general consideration will be given to the uses of steels in different branches of these two applications of engineering.

It is now well known that the word "steel" covers a wide variety of materials. Broadly, one may divide steels into those produced in bulk, i.e., in terms of very large tonnages, and those produced under more specialised conditions for more specialised requirements. The former includes, for example, structural material for bridges, ships and many common requirements in the engineering domestic life of to-day. The materials which form the basis for the production of food containers (subsequently converted into tin plate), wire for many purposes, and ordinary articles of utility, are classed ordinarily as common steel, and whilst they do not in general call for very special properties, they are an important branch of steel production from the point of view of tonnage required. Such materials do not differ greatly, as regards their chemical properties, from wrought iron, which was the ordinary commercial form approximating to nearly pure iron, in use in engineering structures, the best part of a century ago, and which is still in demand for a number of practical applications.

A revolution in the practical applications of iron came about when steel was produced in large quantities in the fluid state. A new revolution, however, took place when it was found that by alloying iron with other elements besides carbon, useful modifications could be obtained in the properties of materials so produced.

In motor-car construction quite a number of parts are still required to be made of steel which might be included in the "ordinary" class. Special attention has been given to the methods of production of such steels, and to the form in which they are applied. One might instance, for example, motor car chassis frames and bodies. These parts, whilst being generally made of steels of ordinary mild steel analysis, receive special treatment in their manipulation which results in their being peculiarly adaptable for the purpose to which they are put.

Many other parts of a motor-car call for properties which either necessitate or can be best met by the application of alloy steels. This applies particularly to the engine parts in which high stresses are the rule, and in which provision has frequently to be made for other special properties in addition to those of mechanical strength.

Perhaps the most outstanding feature in the requirements of steel for the automobile industry is the demand for the highest possible standard of reliability. The functioning of a motor-car depends on the correct operation of every individual item in its structure. Such satisfactory operation naturally depends primarily upon the correct design and the proper scantling, fitting and co-ordination of the various parts. Unless, however, each part can be depended upon to reproduce the properties required for the fulfilment of its own duty, then the whole scheme falls to the ground. In some cases this expression might even be of literal application. It could, however, be readily said that the standard of reliability called for in the materials employed in motor car construction has been, and is being fully met. Whatever may be introduced as new features in the automobile world, the word reliability must remain at the forefront of British construction.

The requirements of the various parts vary considerably according to the duties imposed. The main properties demanded of the steels come under the headings of adequate mechanical strength, adequate toughness or ductility, resistance to wear, resistance to elevated temperatures, resistance to corrosion and oxidation, and in some cases other special physical requirements, such as high or low thermal expansion, special magnetic properties, etc. Associated with all these properties must come also reasonable ease of fabrication into the form and condition required. In certain other cases, and this applies particularly to aeroplane structures, there must be an optimum strength-to-weight ratio consistent with the other necessary properties. It will be appreciated that in automobile construction there is greater freedom of design and of choice of material for the various parts than is the case for aeroplanes. Those parts for which, in the interests of safety, added toughness is deemed to be an advantage, can be made in many cases in a material of slightly lower tensile strength, and, by a suitable modification of the dimensions of the parts, adequate strength can be retained, although perhaps at the cost of the inclusion of extra weight. The restriction against such a policy in the case of aeroplane parts is obvious, and this has meant in many cases the use of higher tensile strength and lower overall factors of safety for aeroplane parts as compared with the corresponding items in the automobile. The demand for reliability must, however, be in no way sacrificed, hence the special attention given in production and in the extremely careful inspection at all stages of materials employed in aeroplane construction.

The needs of aeroplane construction brought into being a large number of new specifications for the various steels supplied, and many of these steels have been specially developed for some particular duty. It is interesting to observe that automobile engineers have, in a large number of cases, also taken advantage of these new products and specifications for their own purposes.

Coming now to some details of the material employed, in these notes the steels employed for the two types of product are considered together. The steels may be classified briefly according to the analysis, and according

to the type of alloying element employed in the composition. Tables I and II set forth the main types of steel employed, and the general mechanical properties which can be associated with them. Table I includes the carbon and lower alloy steels, and Table II the richer alloy steels, including the stainless and heat-resisting types.

are used for situations where resistance to wear combined with substantial general toughness is required. The medium carbon steels are used for miscellaneous parts, such as pins, bolts, etc., the high carbon quality is in many cases employed for cylinders, whilst the highest carbon range includes such applications as valve springs and valve guides. As regards the higher tensile alloy parts, it will

TABLE I.

Class.	Analyses %							Condition.	Mechanical Tests in Condition as used.						
									Tons/sq. in.			% El. in 2 in.	% R.A.	ft./lbs. Izod.	Fatigue ±
	C	Mn	Si	Ni	Cr	Mo	Va		Proof Stress 0·1%	Y.P.	M.S.				
1. Carbon Steels (a)	0·10	0·72	0·06	—	—	—	—	N. 900	1622	17·5	28·5	37	64·5	65	12·0
(b)	0·3	0·67	0·14	0·21	—	—	—	N. 850	17·5	20·7	35	30·2	54·6	32	13
(c)	0·5	0·70	0·18	0·10	—	—	—	N. 820	22	26·0	44·2	24	43·5	18	17
(d)	0·76	0·55	0·19	0·30	—	—	—	N. 820	28	45	63	16	25	3	19·5
2. High Mn (a)	0·41	1·5	0·19	0·30	—	—	—	W.H. 850 T. 620	27	32	46·8	25	58	20	20
3. Cr (a)	0·45	0·66	0·27	0·23	0·93	—	—	O.H. 850 T. 600	52	58	66·5	20	52	40	28
(b)	1·0	0·38	0·18	0·15	1·4	—	—	W.Q. 830	Hardness > 650 Br. 90 to 95 Scleroscope.						
4. Cr Va (a)	0·46	0·57	0·17	0·15	1·4	—	0·18	O.Q. 850 T. 490	72	82·5	87·0	16	48	24	42
(b)	0·46	0·57	0·17	0·15	1·4	—	0·18	O.Q. 850 T. 650	32	48·0	56·0	22	60·4	55	25
6. Nickel (a)	0·12	0·4	0·1	2·2	—	—	—	Refine 880 W.H. 760	16	23	38	32	65	80	15
(b)	0·14	0·29	0·16	4·9	—	—	—	Refine 840 W.Q. 760	27	41·9	60·6	17·5	46·9	24	26·5
(c)	0·39	0·55	0·11	2·96	—	—	—	O.Q. 850 T. 620	35	41·7	49·5	24	63·6	70	21·5
(d)	0·43	0·64	0·19	3·58	0·20	—	—	O.Q. 830 T. 570. O.Q.	53	56·4	63·8	22	61	55	27·0
8. Ni Cr (a)	0·31	0·70	0·14	3·2	0·75	—	—	O.H. 820 T. 600. W.Q.	50	54·5	60	22·0	61	68	26
(b)	0·28	0·50	0·15	4·2	1·5	—	—	A.H. 820 T. 250	65·2	85	106	12	45	12	45
(c)	0·14	0·40	0·21	4·49	1·2	—	—	O.Q. 760	48·3	73	89	18	63·7	30	39
9. Ni Cr Mo Va (a)	0·21	0·54	0·20	3·07	1·5	0·56	0·18	O.Q. 850 T. 640. A.C.	66·8	70·5	74·6	21	67·0	48	32
10. Si Mn (a)	0·52	1·05	1·95	—	0·05	—	—	O.H. 870 T. 520	65	76·9	88·2	15	36	13	43
11. Nitralloy L.K. 5	0·30	0·65	0·35	—	1·60	0·20	1·10	Al O.H. 900							
								T. 600		48·8	62·4	19·0	53·0	44	
								T. 650		44·0	57·6	23·0	60·5	54	
								T. 700		38·0	50·6	28·0	65·0	67	
12. Nitralloy H.C.M. 7	0·20	0·45	0·30	0·50	3·0	0·40	—	O.H. 900							
								T. 600	—	45·6	55·1	22	71	74	
								T. 650	—	40·8	49·6	25	74	83	
								T. 700	—	35·6	44·4	27	76	88	

Temperatures in °C. N = Normalised. W = Water hardened. O.Q. = Oil Quenched. A.H. = Air Hardened. T. = Tempered.

TABLE II.

Steel.	Analysis, %							Treatment.	Mechanical Properties.								
	C.	Si.	Mn.	Ni.	Cr.	W.	Ti.		0·1% P.S. tons/sq. in.	Y.P. tons/sq. in.	M.S. tons/sq. in.	Elong. %	R.A. %	Izod Ft.-lbs.	Brinell	Fatigue Range ± tons/sq. in.	Mod. of Elasticity tons/sq. in
Stainless iron bar	0·08	0·10	0·12	0·15	13·5	—	—	A.C. 950, T. 750° C. A.C.	20·0	24·0	33·9	32·0	72·0	80	163	14·0	13,400
Stainless iron tubes	0·10	0·21	0·32	0·18	13·6	—	—	O.H. 940, T. 700° C. or C. drawn and T.	24·0	31·0	40·8	29·0	71·0	90	196	17·5	13,400
	0·11	0·11	0·33	0·21	13·7	—	—	O.H. 950, T. 550° C.	37·0	43·5	55·2	19·0	57·0	45	262	24·5	13,400
Stainless steel bar	0·27	0·35	0·26	0·29	13·1	—	—	O.H. 940° C., T. 700, W.Q.	34·0	38·5	50·2	25·0	61·5	50	241	21·0	13,700
	0·11	0·13	0·15	1·9	17·9	—	—	Sheet softened 670° C.	31·0	34·0	41·8	19·0	—	—	202	—	13,500
High chromium low nickel steels	0·12	0·29	0·15	2·75	17·7	—	—	O.H. 960, T. 550 W.Q.	39·0	42·7	56·8	19·5	55·8	45	269	23·5	13,500
	0·12	0·29	0·23	2·46	18·32	—	—	O.H. 950, T.	64·1	71·1	80·4	8·0	—	—	377	—	13,500
Austenitic chromium-nickel stainless steels	0·11	0·52	0·29	8·1	18·2	0·61	0·65	A.C. 1,050° C.	15·3	17·5	42·9	60·0	62·0	100	175	17·5	12,900
	0·12	0·55	0·30	8·05	17·9	0·63	0·69	C.R. Sheet and strip	45·0	50·8	66·0	18·0	—	—	—	—	12,500
Chromium-nickel-tungsten valve steels	0·44	1·1	0·71	14·1	14·0	2·05	—	Valves A.C. 950° C.	—	29·0	54·6	39·5	47·5	38	255	20·0	13,000
	0·34	1·59	0·16	10·95	21·39	3·16	—	Valves A.C. 950° C.	20·0	38·0	57·0	25·2	35·0	40	269	21·0	13,000
	0·42	1·42	0·12	20·7	13·5	2·8	—	Valves A.C. 950° C.	20·0	38·0	51·0	26·0	31·0	42	255	20·5	13,000
	0·41	1·75	0·92	28·5	14·4	3·2	—	Valves W.Q. 1,000° C.	—	36·9	48·5	38·0	46·0	19	235	—	13,000
Silicon-chromium valve steel	0·44	3·5	0·52	0·15	8·1	—	—	O.Q. 950, T. 700° C.	45·0	53·2	66·2	16·0	32·0	low	255–286	21·0	12,500

There is not space here to go into the details of the particular parts for which these various steels are applied. In general one might say that the low carbon steels are used for such purposes as sheets, frames, tubes, water-jackets, exhaust manifolds and lowly stressed parts. Such steels, when surface hardened by carburising and quenching,

be noted that there is a wide range of choice. The nickel steels are available in forms giving over 60 tons per square inch tensile strength, or down to 38 tons per square inch tensile strength, the latter being adopted for case-hardened parts where great toughness is required in the core.

Chromium-vanadium and silicon-manganese steels are

(Continued on page 124.)

Applications of Steel Tubing

By A Special Contributor

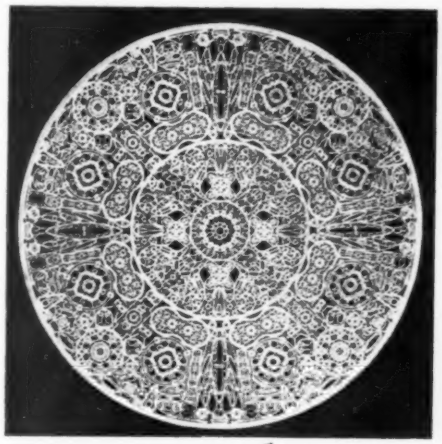
There are very few industries and very few countries in which British steel tubes are not in service; to describe all their uses is practically impossible, but the examples given in this article show how widely they are applied and indicate great development in the last decade.

THE great increase during the past 10 or 20 years in the number of uses for steel tubing has been one of the most spectacular developments of recent times in the direction of new applications of steel and in the replacement by steel of other materials of construction. Any attempt at writing an account of the uses to which steel tubing is put cannot be exhaustive, so it must suffice to give examples illustrating the wide range of industries concerned. In these days, in Great Britain, the sizes of seamless steel tubes commercially obtainable cover most things between hypodermic needles of a few thousandths of an inch and boiler drums of 36 in. diameter or more. Welded tubes can, of course, be made of even larger diameter than seamless, and on comparable sizes are showing a tendency to supplant (in mild steel) what is sometimes rather unhappily termed " solid drawn."

The seamless trade may be subdivided into (i) hot finished and (ii) cold drawn, the essential difference between the two being associated with size, accuracy, and surface finish. For many purposes the hot-finished product is admirably suited, and indeed accounts for very much more of the world's tonnage than cold drawn, but the latter category (as in other industries) covers the products made to much finer tolerances, and/or to small dimensions impracticable on a hot mill, and avoids the relatively rough finish characteristic of hot-rolled or hot-forged surfaces. The hot-produced tube is the raw material for the cold-drawing operations, and as both kinds of work impose severe conditions on the material itself, it is fair to say that the entry of steel tubing into new fields is governed partly by design considerations and partly by the ability of a given steel to stand the punishment of conversion into tube form.

By far the largest tonnage of steel tubing (straight low-carbon steel) in this country is used for carrying gas, water and steam; this must account for hundreds of thousands of tons annually, and is familiar (at least as regards gas and water pipes) literally to the man in the street. With the exception of steam pipes for high-duty service, this tonnage is practically all hot-finished. Boiler and superheater tubes for both land and marine installations are used in hot-finished as well as cold-drawn forms, again for the most part in straight low-carbon steel.

The increasing use of high pressures and temperatures for steam generation, particularly in land power stations, has led to the growing use of steels for superheater tubes that will stand the severer conditions of service: the choice of material and size is governed by the permissible amount of creep and of oxidation by steam and flue gases. Steels that have satisfactory resistance to deformation and attack at high temperatures, have proved to be amenable to tube manufacture; the present tendency is to use the low molybdenum (0.5%), steels with and without about 1% of chromium, in which the carbon is also kept low to facilitate cold-working operations and expanding into tube plates. Occasionally in heat-interchange work of this kind, the stress-carrying capacity is secondary to its resistance to attack by hot gases, and it becomes more important to increase the chromium. Percentages of that element of 3%, 6%, (9% in America), and 13% are commonly used in tubing for high-temperature service;

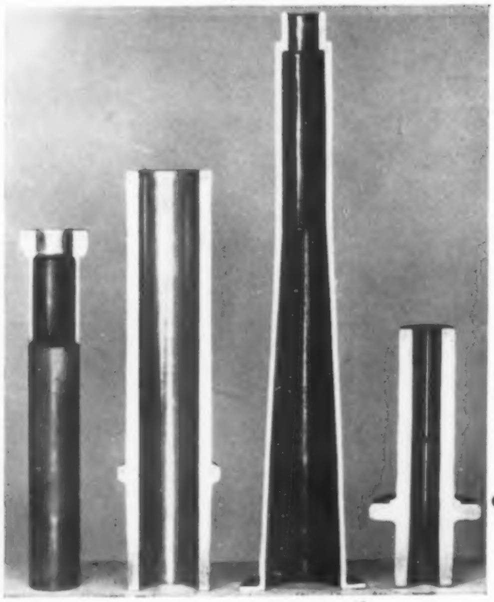


Courtesy of Messrs. Accles & Pollock Ltd.

Filigree design made from 8,050 tube sections.

the carbon is kept moderately low for the reason indicated. More arduous conditions demand the use of austenitic steels possessing to an enhanced degree both creep strength and resistance to scaling, such as the 18/8 chromium-nickel family, of suitable composition to resist the disintegration phenomenon known as " weld decay." For the severest requirements even more highly-alloyed austenitic steels, containing, e.g., 25% nickel and 22% chromium are available in tube form. Alloy steels of this kind have their own peculiar technique during tube manufacture; their very strength at high temperatures means changes in hot-rolling conditions, even to the extent of employing new processes, such as extrusion, in lieu of older methods. In the high temperature field, alloy steel tubing now finds extensive use in steam generation, furnace recuperators, the hydrogenation of coal, and the construction of tubular hot plates for electric cookers.

Another direction in which very large tonnages of steel tubes are in use is that of gas cylinders. For very low pressure work, such as containers for butane, propane, and the like, seamless tubes are unnecessary, and thin vessels of welded-sheet construction are common. For the greater pressures employed in the transport and storage of liquefiable gases, and higher pressures still for the so-called " permanent " gases, seamless cylinders are standard. These consist of steel tubes with the ends closed by forging, the materials for moderate and high pressures being 0.15–0.25% carbon steel and 0.40–0.48% carbon steel respectively. Since weight is a consideration in the handling and transport of gas cylinders, attention has been directed to the use of alloy steels. The simplest of these, 0.35% carbon with 1.5% of manganese, is universal in the States, where there are some five million cylinders of this composition in use; extensive trials are in hand with a view to its adoption in this country. For special purposes where containers have to hold gases at very high pressures, e.g., 3,000 lb./in.^{2}, nickel-chromium-molybdenum structural steels are employed having tensile strengths of the order of 70 tons/in.^{2} Cylinders of all these types are made in a variety of shapes and sizes from small soda-water syphon



1 2 3 4

Courtesy of Messrs. Tubes Ltd.

(1) Piston tube for aero landing-gear recoil; (2) Sleeve for change speed box; (3) Automobile axle tube; (4) Stub axle for aero landing wheel.

"sparklet" bulbs to giant air reservoirs of 2 ft. and 3 ft. diameter.

The oil industry has been responsible for much development in steel tubes during the last decade or two, particularly in America where large oil fields and an efficient tube industry co-exist. On this side of the Atlantic, Great Britain supplies much of the requirements of European and Asiatic oilfields as does also the highly-developed tube industry of the Continent. Each oil well needs its drill pipe and casing pipe and in these days large steel mains carry oil for great distances. The famous Iraq pipe line includes some 320 miles of $12\frac{3}{4}$ in. o.d. $\times$ 0.33 in. thick mild-steel seamless tubing made on one mill in this country. In the United States, seamless steel pipes are used for conveying both oil and natural gas from the fields of the south to the industrial areas of the north and west; there are some 300,000 miles of such piping, about 115,000 miles of which are carrying oil. In that great country, too, oil wells are anything up to 13,000 ft. deep and there are 400,000 of them. "Oil-country goods" also includes tubes for cracking stills, generally 4 in. or 5 in. diameter and around $\frac{1}{2}$ in. thick, in lengths of 30 ft. and more. Since these are subject to high temperatures and pressures, this is another direction in which high-chromium and austenitic steels are finding increasingly wide application.

Modern transport is dependent to a surprisingly large extent on steel tubes. The principal needs of the railways are, of course, locomotive tubes, which are cold-drawn mild steel, used in the annealed condition. Improved power-weight ratios call for considerable use of alloy steels (nickel and nickel-chromium types) in automobile construction. A typical present-day motor car may contain something approaching a hundred tubular parts, including axle casings, propellor shafts, steering columns, chassis cross-members, wind-screen frames, etc. Some of these tubes are subject to intricate operations of swaging, staving, upsetting, expanding, tapering, flanging, and the like; this phase alone is constantly leading to new and complicated forging technique and better service to the automobile designer. Associated with land transport, one must also include street-lighting poles (fluted, plain and otherwise), and even the Belisha beacon stands on its steel tube, like many other road signs and traffic lights; the bicycle is essentially made of steel tubes, either welded or seamless, generally in mild steel, or in manganese-molybdenum and chrome-molybdenum steels for the light weight racing type. It is probably in recent development and increased production in aircraft that the tube industry has had to pay most attention to improved production methods and new materials. Tubing is supplied in what seems to be too great a variety of specifications for various aircraft purposes, such as fuselage construction, landing gear, cylinder liners and other engine parts. The activity of this section of the industry has increased considerably of recent years, and, with the existing rearmament programmes, is now one of major importance. Aircraft tubing is often highly-stressed, and to satisfy the demand for both high mechanical strength and low weight, alloy steels are almost invariably used. A very large variety of special sections and manipulated forms is supplied, including bent tubes, oval, stream-lined, and tapered tubes, and welded structures such as engine nacelles and fuselage skeletons. The introduction of retractable undercarriages, wing flaps and other hydraulic controls has increased the importance of the production of precision tubing, and the demand for specially close, dimensional tolerances and high surface finish have been met by continued improvement in technique. The shipping industry has set fewer metallurgical problems, although high degrees of superheat occasionally call for molybdenum steels, but as all who have visited the engineering quarters of our large liners and naval vessels will at once recognise, they contain literally miles of steam pipes, boiler tubes, service pipes, hand railing, derricks and miscellaneous tubular parts.

Industries that use large tonnages of steel tubes must also include chemical manufacture, in which special materials have had to be developed in tube form for resisting the action of the multiplicity of chemicals now produced on a large scale. Particularly is this true of the manufacture of synthetic ammonia and associated products, and of petrol from coal. The major industries, however, by no means exhaust the uses of steel tubes; in the home they are employed in such equipment as vacuum cleaners, electrical conduit, bedsteads, refrigerators, electric heaters, and tubular furniture; in the realm of sport tubular golf shafts (alloy steel, hardened and tempered), are used practically everywhere; they are only about fourteen thousandths of an inch thick at the butt-end, and present nice mechanical and metallurgical problems in manipulation and heat treatment; squash-racket handles, ski-sticks and tent poles are made of steel tubes; so were the cross-bracing struts of the "Endeavour." Fishing rods of steel tubes are increasing in popular favour. Underground, tubes figure as pit props and as casings for miners' safety lamps. The medical profession not only uses them in instruments (including hypodermic needles of austenitic nickel-chromium stainless steel), but also as containers for gases for anæsthetic purposes. The food industry employs steel tubes in the manufacture of fruit juices, soups, etc., and for the conveyance of milk. The brewing industry is using large quantities of stainless tubing. Frames for holding printers' type are rectangular-section, cold-drawn, seamless steel tubes of very high precision. Tubing other than of circular cross section has, in fact, been common for a long time, and one makers' catalogue lists about a thousand different shapes for which tools are on hand.

There are very few industries and very few countries in the world in which British steel tubes are not doing duty. To enumerate all their uses would be virtually impossible, but the examples given in these notes may serve to support the opening reference to the great development of the last 10 or 20 years.

Steels for Power Plant

By H. H. Burton
Chief Metallurgist, English Steel Corporation Limited

Power plant has a wide interpretation, but in this article the author confines his attention to steels used in plant for the generation of electricity. A selection of steels is discussed which are being used and developed for plant concerned in the raising of steam and its conversion into mechanical energy, and that employed in the conversion of mechanical into electrical energy.

FOR the purpose of this article, it will be assumed that the term "Power Plant" refers to plant for the generation of electricity, the prime mover being the steam turbine. So far as the writer is aware, no other system has been employed, or is contemplated for any of the large power stations forming part of the Grid Scheme in this country, and it seems logical to assume that no radical change is likely to occur in Great Britain for some time to come.

The apparatus and machinery in such generating plant is essentially of two types :—

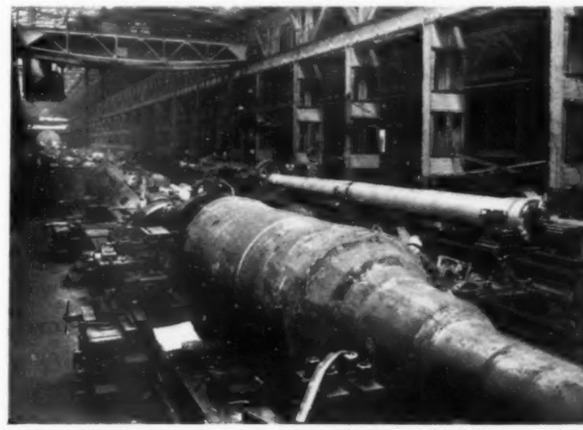
A. That concerned in the raising of steam and its conversion into mechanical energy.

B. That employed in the conversion of mechanical into electrical energy.

Space does not permit a really exhaustive discussion of the various steels which are being used and developed for all the items coming within these two categories as defined above, and the writer has, therefore, made a selection of some cases which seem likely to be of particular interest.

Under heading "A" must be included a number of items for which special steels either have become or may become necessary. These include boiler drums, superheater tubes and headers, pipe flanges and pipe flange bolts, and parts of the actual steam turbine itself such as rotors, casings, etc.

Under heading "B" is perhaps only one item which presents very special problems from the point of view of the steelmaker and metallurgist, and this is the generator rotor.



Courtesy of English Steel Corporation Ltd.

Alloy steel rotor body forging before rough machining. Forged weight approximately 64 tons.

Boiler Drums

For the great majority of power plants which have been designed up to the present, carbon steel boiler drums have been perfectly satisfactory with ranges of working pressures between, say, 650 and 850 lb./sq. in., and corresponding temperatures of from 495° F. to 525° F. (268° C. to 280° C.). There are, however, a fair number of installations already working at pressures up to 2,000 lb./sq. in. and corresponding steam temperatures up to 636° F. Under these latter conditions and still more in those fewer cases where pressures as high as 3,000 lb./sq. in. and steam temperatures up to 696° F. are met with, the possibility of the employment of alloy steel drums is being seriously considered.

The chief difficulty which accompanies the use of carbon steel for these high temperatures and pressures is that the drums have to be made abnormally thick in the wall, in order to withstand the stresses set up. In the case of large drums especially, this heavy wall thickness not only involves the employment of a very large ingot, but, in addition to this, the weight of the finished drum is liable to be so great that difficulty may arise in designing a satisfactory system of suspension. The requirements of a suitable material for working at high stresses in the region of, say, 680° F., do not involve the highest obtainable creep strength, since creep is not a serious problem at this temperature, but rather a high elastic limit at the working temperature. This property is exhibited to a greater or less extent by a number of the alloy steels now used for general engineering purposes, some of which do not exhibit specially high resistance to creep at more elevated temperatures, say, of the order of 900° F. and upwards. At the writer's firm, the properties of a number of such steels have been studied in relation to their possible employment for the construction of boiler drums, and of these steels two types of chromium-molybdenum steel are considered to offer considerable attraction for development along the lines indicated. The first of these steels is a low chromium-molybdenum material, having the following range of composition :—

Carbon	0·18 to 0·25
Manganese	0·40 to 0·60
Chromium	0·50 to 0·80
Molybdenum............	0·40 to 0·60

The corresponding range of properties at atmospheric temperature is as follows :—

0·05% Proof Stress	19 tons/sq. in. minimum.
Maximum Stress	32 to 38 tons/sq. in.
Elongation	22% minimum.

Following upon the argument previously put forward in this article, that for service at 680° F. the important

Forged boiler drum and steam receiver recently made for use in a super power station in the Midlands.

Courtesy of English Steel Corporation Ltd.

property is the stress up to which the material will remain elastic, the following figure for the 0·05% proof stress at the temperature mentioned may be taken as a safe criterion upon which to base stress calculations :—

0.05% proof stress at 680°F......... 14 tons/sq. in.

This figure is, of course, considerably higher than that for a plain carbon steel of corresponding tensile strength at normal temperatures, and, in consequence, a thinner walled, and hence a lighter drum may be designed by the employment of a steel of this type.

There are, however, cases where it is desirable still further to reduce the wall thickness, and hence the weight of the drum, and in such cases the following type of steel is considered to be eminently suitable :—

Carbon	0·22 to 0·28%
Manganese.............	0·40 to 0·60
Chromium	3·0 to 3·5
Molybdenum............	0·45 to 0·60

The possibilities of this steel for boiler drums are not based solely upon laboratory experiments, for it will be realised that a steel of this type has been employed quite extensively by the author's firm, and others, in the manufacture of vessels for chemical plant operating at high temperatures and pressures.

A range of mechanical properties corresponding to properly heat-treated material of the preceding composition is as follows :—

0·05% Proof Stress......	28 tons/sq. in. minimum
Maximum Stress	42 to 48 tons/sq. in.
Elongation	18% minimum.

At the working temperature which is being taken as an illustration in this article (680° F.), actual tests cut from a large hollow forging have given the following mechanical properties :—

	Tempered at 690° C.	Tempered at 720° C.
0·05% Proof Stress..	28·8 tons/sq. in.	26·5 tons/sq. in.
0·2% „ „ ..	31·4 „	28·5 „
Maximum Stress	41·2 „	39·4 „
Elongation	18%	19%
Reduction of Area ..	48·5%	52·4%

Assuming that design calculations for the permissible stress in a boiler drum are based upon the 0·05% proof stress value, which the author believes to be a sound practice for the temperature range considered, it is obvious that the properties of this steel are such as to permit a very considerable decrease in the wall thickness of the drum, and a consequently large saving in weight.

It has been often advanced against the use of alloy steels for such parts as boiler drums, that such steels are more prone to cracking during manufacture than carbon steels, and are also liable to embrittlement, as judged by the Izod test, after a period of service. It is the author's firm conviction, based upon considerable experience and research, that in both these respects the chromium-molybdenum steel has marked advantages over some of the more complicated nickel-chromium-molybdenum steels. One obvious reason for this difference is that the austenite-pearlite change occurs at quite a high temperature (about 700° C.) in the chromium-molybdenum steels if they are slowly cooled from a high temperature—a feature which is not characteristic of the nickel-chromium-molybdenum series—and hence the former type of steel is much less liable to cracking during manufacture through stresses set up in passing through the transformation range. So far as embrittlement is concerned, there is ample evidence to show that a steel of the type under consideration is particularly free from this peculiarity, which is regarded by many engineers as being a point of major importance.

Superheater Tubes and Headers

Both these parts have to meet considerably higher temperatures than are encountered in the previous case just dealt with. At the present time there are various installations working in this country where the superheated steam temperature is as high as 932° F. (500° C.), and since experimental installations are already working in the United States with a superheated steam temperature of 1,000° F., it is to be expected that similar conditions will have to be met in the near future.

An important problem which arises in connection with these parts is that of the relative importance of resistance to creep and resistance to scaling in the materials employed, and unfortunately these two properties do not tend to be combined in the same type of material.

In consequence of this, it is not uncommon to meet with marked differences of opinion as to the best material to employ for a particular superheater installation. So far, in this country, the alloy steel which has been most widely employed is a carbon-molybdenum steel containing about 0·5 to 0·8% of molybdenum, but three other materials are being extensively studied in connection with this application :—

1. A low chromium-molybdenum steel containing 0·5 to 0·8% of chromium, and 0·4 to 0·6% of molybdenum.
2. A steel containing about 6% of chromium and 0·5% of molybdenum.
3. A molybdenum-vanadium steel containing about 0·5 to 0·7% of molybdenum and 0·2 to 0·3% of vanadium.

The opinions of different investigators differ considerably with regard to the respective creep properties of these three steels, but it is now generally admitted, by those who have investigated the matter thoroughly, that the 6% chromium-molybdenum steel is inferior, so far as creep strength is concerned, to either of the other two, and its chief claim as a material for superheater parts lies in its superior resistance to scaling at high temperatures. Whether or no this is of sufficient importance to offset its inferior creep performance, seems still to be a matter for further investigation, but it is significant that in a recent paper presented at the annual meeting of the American Society of Mechanical Engineers, R. M. Vanduzer, Jr., and Arthur McCutchan make the following comment : "Present indications are that oxidation of the carbon-molybdenum test sections will not affect the expansion of the tubes to an appreciable extent at 925° F. The inside and outside surfaces are covered with a fine reddish-brown oxide with no evidence of scaling." This suggests that, contrary to a commonly held view, resistance to oxidation is not the most important problem in connection with superheater parts, and it may be inferred that even at somewhat higher temperatures the problem of scaling is not so serious as has been anticipated.

So far as resistance to creep is concerned, there is little doubt that the steel with much lower chromium content has considerable advantages, and work which is proceeding in the author's and various other laboratories indicate that the molybdenum-vanadium steel is still better. Indeed, the indications are that when tested at a temperature some 50° C. higher than either a low chromium-molybdenum steel, or a plain carbon-molybdenum steel, the molybdenum-vanadium steel has equally good creep strength. This steel was one of the materials dealt with in a recent paper by T. F. Russell and the writer, which was printed in *The Journal of the Iron and Steel Institute*, Vol. 2, for 1938. The steel is characterised by marked temper hardening after quenching and tempering over a certain temperature range, and the correlation of this temper-hardening characteristic with the creep properties of the steel, is the subject of a study which is proceeding at the present time.

Pipe Flange Bolts

It is not possible in the space of this article to enter into a detailed discussion of the merits and demerits of the various steels which have been suggested for this purpose, but it is now generally agreed that for temperatures up to about 900° F., a low chromium-molybdenum steel gives an excellent combination of high creep

strength and freedom from embrittlement. The steels of this type in use vary in chromium content from about 0·6 to 0·8% in one type of steel, and 1·3 to 1·5% in another, with a corresponding molybdenum range of about 0·5 to 0·7%. With a steel having the lower range of chromium content, water hardening and tempering is necessary in order to obtain high tensile strengths of the order of 55 to 60 tons/sq. in., but a steel of this type has slight but distinct advantages in creep strength over that containing more than 1% of chromium.

For the still higher temperature range of, say, 900 to 1,000° F., the molybdenum-vanadium steel, discussed previously under the heading of superheater parts, seems to offer very great promise, but it should be noted that with a steel of this type, unless the parts are of small diameter, it may be found necessary to modify the tensile figures at normal temperatures, which are demanded by most existing specifications. In the writer's laboratories, this steel has been investigated in bar sizes up to approximately 10in. in diameter.

In parts of this size the following properties have been obtained in a steel containing about 0·15 to 0·2% of carbon, 0·6% of chromium, and 0·3% of vanadium, the treatment consisting of oil hardening from 920° C., and tempering to 690° C. :—

Yield Point	28 tons/sq. in.
Maximum Stress	35 ,,
Elongation	30%

Bars of smaller size—in this case 5in. in diameter—have given the following figures :—

Yield Point	32 tons/sq. in.
Maximum Stress	42 ,,
Elongation	27%

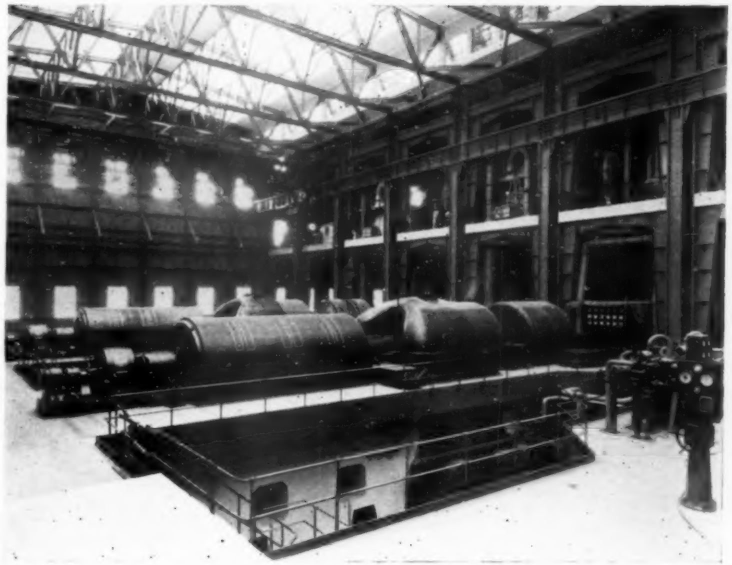
These figures are given merely as an indication of what can be obtained in the case of bolts and studs of specially large size, and particular attention is drawn to the very high ratio of yield point to maximum stress when the latter values are still only moderately high. Since it is presumably the yield point or the elastic range which is the important feature, in such parts, it seems feasible that this material may be employed for many purposes where an exceptionally high maximum stress is not considered to be necessary. Indeed, it is difficult to see what value a high maximum stress at normal temperatures can have in the case of parts working at temperatures as high as 500° C., unless this high maximum stress is accompanied by correspondingly high creep and elastic properties at the working temperature.

Turbine Rotors

So far alloy steels have not been extensively used for these parts, but there are already in existence a certain number of turbine rotors made from carbon-molybdenum steel with a molybdenum content averaging about 0·5%. Such rotors have generally been supplied to the requirements of B.E.A.M.A. Grade II Specification. It is not impossible that a steel such as the molybdenum-vanadium material, which has been dealt with previously, may find some applications in this field also, but the writer is not aware that this has been done so far.

Turbine Casings

For the more modern installations, where the superheat is as high as 932° F., carbon-molybdenum steel turbine casings are being used to a considerable extent, and if the temperatures rise above this figure, as seems extremely likely, it is probable that molybdenum-vanadium steel may find still another application in this direction. As some of these parts have to be heat-treated in complicated shapes and considerable masses, it is obviously an advantage to employ a steel which will give the desired properties without any drastic quenching operation, and much further research is necessary with this end in view.



Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

2—75,000 k V.A., 0·8 p.f., 1,500 k p.m., 11,000 volts. Metropolitan-Vickers Turbo-Alternator Sets at the Fulham Corporation Power Station. A third similar set has recently been installed.

Generator Rotor Forgings

These forgings present many difficult manufacturing problems, not only on account of the fact that mechanical properties of a high order are necessary, especially for rotors running at 3,000 revs. per minute, but because these forgings are some of the largest now made which have, of necessity, to be forged and heat-treated solid.

Suitable steels for this purpose must be capable of providing the necessary magnetic characteristics desired for a rotor forging, and must also be capable of giving the necessary high yield point, maximum stress, and ductility right to the centre of the forging.

It should be appreciated, in connection with this last remark, that the stresses set up at the centre of a rotor forging revolving at high speed are very considerable, and for this reason some form of alloy steel has become inevitable. In choosing such a steel it is most important, however, that the desired properties should be obtainable without the necessity for quenching the forging in the process of heat-treatment, since the internal stresses left in the forging after this quenching operation are almost impossible to remove to a sufficient extent by subsequent tempering.

For the most highly stressed types of rotor which the writer has encountered, a steel of the following composition has been found to give excellent properties :—

Carbon	0·3% approximately.
Nickel	3 to 3·5%
Molybdenum............	0·2 to 0·3%

Typical tests which have been obtained from such a forging approximately 36in. in barrel diameter are as follows :—

Yield Point :	Tangential	37 tons/sq. in.
,, ,,	Radial	,, ,,
Maximum Stress :	Tangential	47 tons/sq. in.
,, ,,	Radial	
Elongation :	Tangential and Radial......	17·5%
Bend :	Tangential and Radial	180°

Core Tests

	Near bottom of Barrel	Near top end of Barrel
Yield Point	36 tons/sq. in.	34 tons/sq. in.
Maximum Stress ..	49 ,, ,,	44 ,, ,,
Elongation	24%	24%

(continued on page 124.)

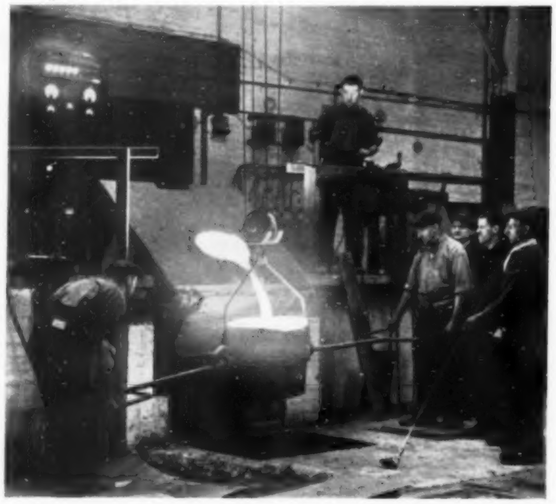
Modern Tool Steels

By L. K. Everitt, B.Met.

The production of tool steels, which received an impetus by the development of the crucible process, has been greatly widened and increased during the past twenty years. Some of these developments are briefly discussed.

WHILE in point of tonnage the amount of steel consumed in the production of tool steels is not large in comparison with other sections of the industry, tool steel has so many important uses and is so essential to modern manufacture that it cannot be ignored. From the historical point of view, it is probably the most interesting of all steels. From the time of Chaucer, when steel knives are known to have been made in Sheffield, down to the present day, tools have been made from the finest of steels.

It was not, however, until Benjamin Huntsman developed the crucible process for making tool steels that it became possible for the tool maker to depend, without uneasiness, upon the steel he used. In this connection it is interesting to remember that the Huntsman process will celebrate its bi-centenary next year. By this process the ingredients of the steel, exactly weighed and classified, are melted up in a clay crucible heated by coke or gas. Today, the process, though still in existence, is being increasingly supplanted by the high-frequency electric crucible process, in which the melting heat is induced in the metal itself by the passage of high-frequency electricity through a copper coil surrounding the crucible. This electricity sets up eddy currents in the steel, and the great advantages are closer control of temperature, complete freedom from contamination by the fuel, and more thorough mixing of the heavy alloys used in making modern steels. This process Edgar Allen & Co., Ltd. were the first in the world to introduce for the commercial manufacture of fine tool steels. In 1927, they demonstrated, before a large gathering of nearly 100 of the world's Pressmen, the first manufacture of "steel in a wooden box," as it was then called.



Courtesy of Edgar Allen & Co., Ltd.

Teeming tool steel from a high-frequency furnace.

High-speed Steels

Turning now to the steels themselves, the first great branch is, of course, the high-speed cutting tool steels. Of these, the most recent and, for its special purposes, the most effective, is the super-high-speed steel, containing approximately 21% of tungsten and 11–12% of cobalt, together with other alloys such as chromium, molybdenum, vanadium, etc. This steel will turn and drill, on a production basis, materials hitherto commercially unmachineable, such as high manganese steel (12–14% manganese). Next to this is another super-high-speed steel with a lower cobalt content, but containing 18–20% of tungsten, together with chromium, vanadium, etc.

The original 18% and 14% tungsten steels still continue to be used for general purposes, though the increase in the pace of production in modern shops has tended to oust the 14% tungsten material from many in which it was formerly used.

Another interesting feature is the growing tendency to use butt-welded tools, consisting of a welded end of super-high-speed steel, electrically butt-welded to a high-grade steel shank. These tools will do all the work that a solid tool will do, and they have the advantage that they reach the user completely ready for use, being heat-treated and hardened by experts, while the standardised tool shapes have also been carefully chosen to meet the requirements of the modern machine shop.

Die Steels

The second great branch of tool steel production may be said to include the die steels, of which there are many of widely different compositions. Probably the best known and most generally used of these is the oil-hardening die steel, based on the use of manganese, chromium and tungsten as alloy ingredients. This is a good all-round, non-shrinking die steel for normal dies. Where exceptional outputs, combined with the minimisation of distortion after hardening are required, a higher quality of steel, of chromium-molybdenum-vanadium type, has met with great success. This is a more expensive steel because the percentages of alloys are higher; but it is admirable for intricate sections and for punches for thin materials.

Many other types of dies can be made from it, and its great feature is long life of the cutting dies. A good example of the class of tool made with great success from this steel is thread rolling dies.

A third class of die steel is for special shear blades, cold press work, certain kinds of general dies, etc. This is a chromium-molybdenum-cobalt steel.

Two steels for pressing dies then call for mention. One of these, of chromium-tungsten type, is for pressing or squeezing dies, though it is not suitable for drop-stamp dies. It resists the heat and shock encountered in hot process work, and has been applied with great success in hot nut and bolt production. It has also been used for hot shear blades. The second steel of this type is a tungsten-chrome-vanadium steel, fulfilling purposes similar to those of the previous steel. It is, however, of higher quality. Two other die steels are specifically designed for die casting. The first of these is a tungsten-chromium-molybdenum steel, specially for long runs; the second is a chrome-vanadium steel for dies from which only a small quantity of castings are required, but where high-melting alloys are dealt with and long life desired.

Steels for Pneumatic Tools

Another steel deserving mention is one that has been introduced for pneumatic chisels, etc. This is a tungsten-chrome-vanadium steel, oil-hardening, and requiring no tempering; it holds a keen cutting edge, exceedingly resistant to wear, and its cutting efficiency, and the speed with which it removes material, makes it highly economical.

There is a second steel of oil-hardening type for chisels,

(Continued on page 118A.)

SHIPBUILDING STEELS

By J. W. Donaldson, D.Sc.

The shipbuilding and marine-engineering industries consume a considerable tonnage of steel and in this article particular reference is made to the steels used in ship construction together with trends in their development.

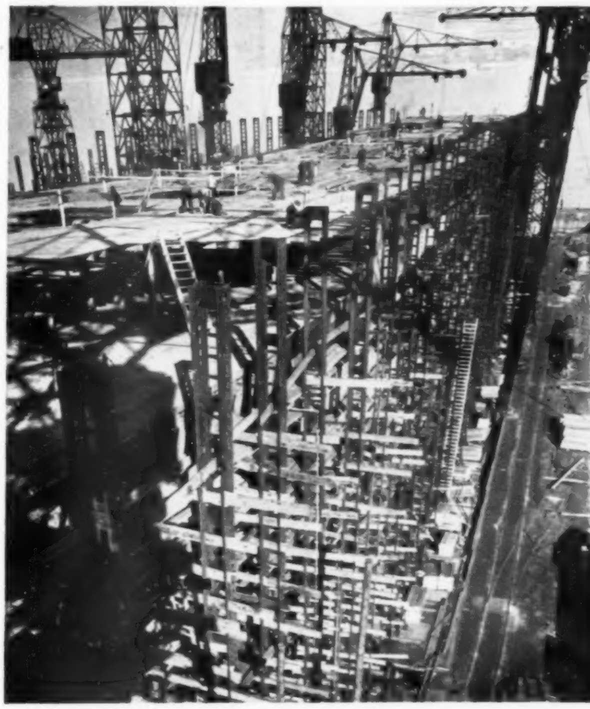
IN the United Kingdom last year over 400 ships were built, giving an output of over 1,136,000 gross tons. As practically all those ships were built of steel, the amount of steel utilised in their construction approximated to some 400,000 tons. This figure takes into account only the steel used in hull construction, and does not include the large quantity of steel used in the construction of engines and boilers required for ship propulsion. Steel required for the shipbuilding and marine engineering industries therefore forms a considerable tonnage and renders those two industries of great importance to steel production.

Mild steel has invariably been used for hulls, decks, deck houses, etc., ever since steel has been used for shipbuilding, and still forms the bulk of the tonnage used for such purposes. Steel of 26 to 32 tons per sq. in. tensile strength in the form of plates, angles, sections, and bars gives satisfactory results, not only as regards strength and resistance to corrosion, but also as regards cost and ease of fabrication, as such steel is easily punched, and sheared by ordinary shipyard methods. Higher tensile steels and steels of high elastic limit have also been used for some considerable time, but their use is by no means general, although the quantity of such steels used has increased considerably during recent years. In Table I are given the steels generally used in hull construction.

TABLE I.

Steel.	Limit of Proportionality Tons per sq. in.	Ultimate Stress Tons per sq. in.	Elongation on 8 in. %
Lloyds Mild Steel	—	26—32	20
Admiralty M.S.	—	26—30	20
Admiralty H.S.T.	—	30—34	20
Admiralty D.	17	37—44	17
Lloyds Elastic Limit	15	33—38	20
Elastic Limit Mild Steel	15	29—34	17

High tensile steels are employed chiefly in Admiralty construction to allow of a saving in weight, and the same factor applies to elastic limit steel, where the higher limit of proportionality allows the material to be more highly stressed and its thickness correspondingly reduced. High elastic limit steels are of two types, those which can be fabricated by the same methods as mild steels, and those which require special methods in working, such as drilling instead of punching, similar to high tensile steels. The former type of elastic limit steel is essentially a heat-treated mild steel, the higher limit of proportionality resulting from the heat-treatment, while this property in the latter type depends essentially on a higher carbon content and greater control in casting and rolling. The use of 50% of either type of this steel in the construction of a ship in place of mild steel permits of a reduction in scantlings of about 10 to 12%, and yields a saving in weight of from 300 to 500 tons according to the size of the ship. High elastic limit steels are used chiefly in naval construction, although their use in merchant work is extending both for large passenger liners and cargo ships. In the *Queen Mary*, 4,500 tons of elastic limit mild steel were used in the structure, and in the *Normandie* over 6,000 tons of a higher tensile elastic limit steel.

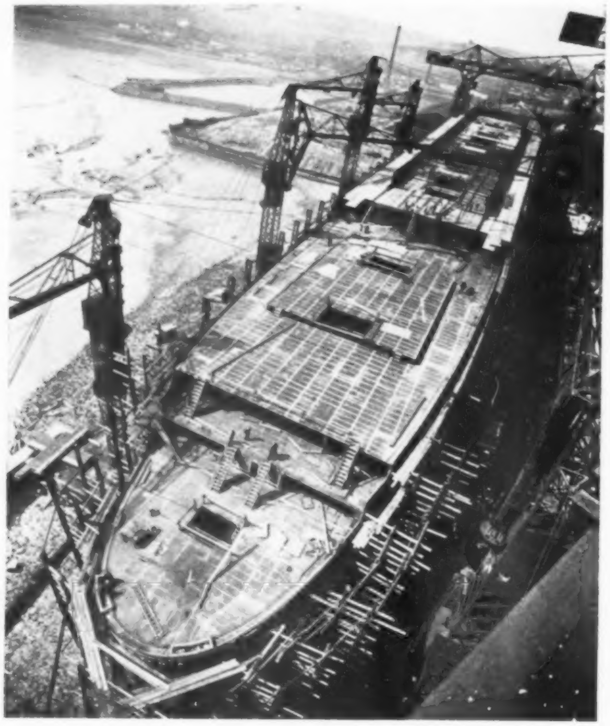


Courtesy of The Cunard White Star Co.

A fine view of the "Mauretania" under construction, showing the enormous height of the vessel.

Special steels used in hull construction with a view to reducing corrosion are alloy steels containing copper, chromium, or molybdenum. Copper content steels containing 0·2 to 0·3% copper are sometimes specified and used for hull plates, as being more resistant to corrosion by sea water than mild steel of similar carbon content. For parts not actually immersed in water such as decks, deck houses, davits, derricks, funnels, masts, etc., low alloy steels containing either 0·25 to 0·5% copper and 0·7 to 1·1% chromium or 0·25 to 0·5% copper and 0·1 to 0·3% molybdenum are being increasingly used, as such steels have a better resistance to atmospheric corrosion than has mild steel. Stainless steels are not used in shipbuilding to any extent on account of their cost, except where steel of the 18/8 type is used for decorative purposes in high-class passenger liners and in naval ships for certain screws, sheets, and tubes.

Mild steel is also used in ship construction in large quantities in the form of rivets and in small quantities in the form of forgings. Low carbon steel or ingot iron rivets to Lloyds specification have a tensile strength of 21 to 25 tons per sq. in. and an elongation of 25%, and mild steel rivets to the same specification are of 26 to 30 tons per sq. in. tensile strength and 25% elongation. In Admiralty work only mild steel rivets are used, except when riveting H.S.T. and D quality steel, when rivets are made from bars of 35 to 40 tons per sq. in. tensile strength and 17 tons per sq. in. elastic limit. For forgings, mild



Courtesy of The Cunard White Star Co.

The new "Mauretania," which recently completed her maiden voyage, under construction at Cammel Laird's Birkenhead Shipyard.

Courtesy of The Darlington Forge Ltd.

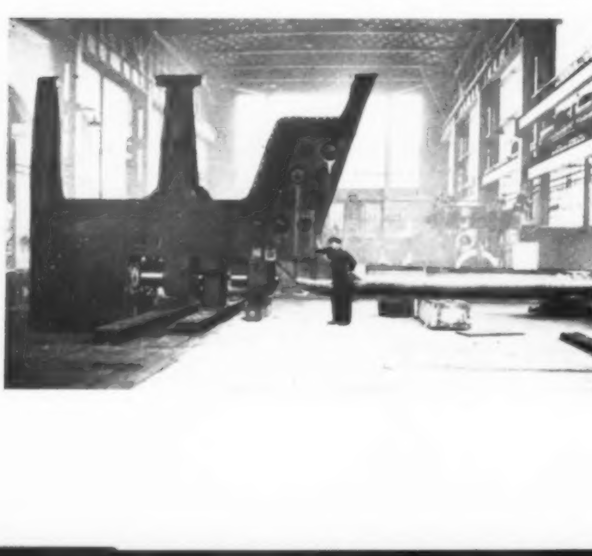
The stern frame for the "Queen Mary" comprises five steel castings and weighs about 190 tons. This stern-frame together with the shaft brackets and rudder castings used about 600 tons of steel.

steel of 28 to 32 tons per sq. in. tensile strength is sometimes used for such parts as anchors, propeller posts, propeller shafts, rudders, rudder heads, shaft brackets, and stern frames. When such parts have to be welded a lower tensile steel of 22 to 26 tons per sq. in. is usually specified, and where higher strengths are required steels of 31 to 35 or 34 to 38 tons per sq. in. are employed. For certain forgings in Admiralty construction and high class merchant work 3·5% nickel steel or heat-treated nickel-chromium steel are used in very small quantities. Steels of varying tensile strengths ranging from 22 to 40 tons per sq. in. are also used in fair quantity in the form of tubes for such parts as ventilators, tubes for control and valve shafts, and tubes for davits, derricks, and masts.

Steel castings are generally used for the stem, stern frame, rudder frame, rudder stock, and propeller brackets of a ship, except where stem and stern posts and propeller

This rudder frame used on the "Mauretania" is 36 ft. 6 in. high and 22 ft. wide. It is made in two pieces, the upper a forged steel stock and the lower a steel casting. The rudder stock is the largest ever made by The Darlington Forge.

Courtesy of The Darlington Forge Ltd.



brackets fabricated from plates and forgings by welding have replaced castings, and for smaller parts such as anchors, bollards, fairleads, brackets, handwheels, etc., and the steel used for such castings usually has a tensile strength of 26 to 35 tons per sq. in. and an elongation of not less than 20% when annealed. Where castings of greater strength are required a tensile strength of 30 to 37 tons per sq. in. is generally specified. During recent years there has been a tendency to introduce alloy steel castings for stern posts and rudder frames, and the steel selected for such parts is one containing a small percentage of vanadium, as the addition of vanadium raises the strength slightly, increases the toughness and hardness, and gives a casting with a much better grain structure. The use of castings of more complex vanadium alloy steels, where the vanadium is alloyed with manganese, chromium, or nickel has also been suggested on account of their greater strength and the fact that they are easily heat-treated. For castings subjected to hard wear such as fairleads for bollards, roller fairleads, and bearings, 12 to 13% manganese steel is sometimes used.

The weight of steel castings in a ship's structure depends on the size of the ship and may vary from 50 tons in the case of a medium-sized cargo ship to hundreds of tons in a large passenger-liner. In Table II are given the weights of the large steel castings made for such ships as the *Normandie, Queen Mary, and Queen Elizabeth.*

TABLE II.

Casting	*Normandie*	*Queen Mary*	*Queen Elizabeth*
Stern Frame	102	190	190
Rudder Frame	67	110	120
Rudder Stock	47	—	120
Propeller Brackets, aft...	112	180	180
Propeller Brackets, ford.	84	120	120
Stem	33	—	—

The sternframe of the *Queen Mary* which is shown in an accompanying illustration is made in five sections, included in it are the gudgeons in which the rudder swings and the trunk through which the rudder stock passes from the rudder, through the ship, to be connected to the steering engine. The castings for this vessel also include two outer and two inner shaft brackets, the former comprising four sections and the latter two, and a large box-section casting which acts as the rudder main-piece and forms the the foundation for the rudder. The production of these large castings is complicated by their awkward shape, necessitating a special technique.

STEEL WIRE

By Alastair T. Adam

(Bruntons (Musselburgh) Ltd).

TO discuss in a brief article the properties of steel wire for all, or even a few, of the many purposes to which it is applied, is obviously impossible. Fortunately, such a complete consideration of the subject is unnecessary. For this purpose wire can be conveniently grouped, and the properties of one example from each group may be taken as typical.

Group 1 comprises mild steel wire only, which has a useful range of from 25 to 60 tons per sq. in. tensile strength, according to diameter. In the soft, annealed condition it has many well-known applications,—e.g., telegraph wire, where the carbon content is kept as low as possible so that the wire is virtually iron wire and the electric conductivity is relatively high. In the lightly cold-drawn condition, mild steel wire has peculiar virtues of toughness and is used for many purposes where wire with a little " bone " is required,—e.g., bale-tying wire.

In the hard-drawn condition, mild steel wire should be used with discretion and where tensile strengths beyond 60 tons per sq. in. are required it is generally safer to use patent steel wire. A good example of hard-drawn wire is railway signal wire with tenacities between 40 and 50 tons per sq. in. It is used either as a single wire or as strand composed of seven wires and is always galvanised.

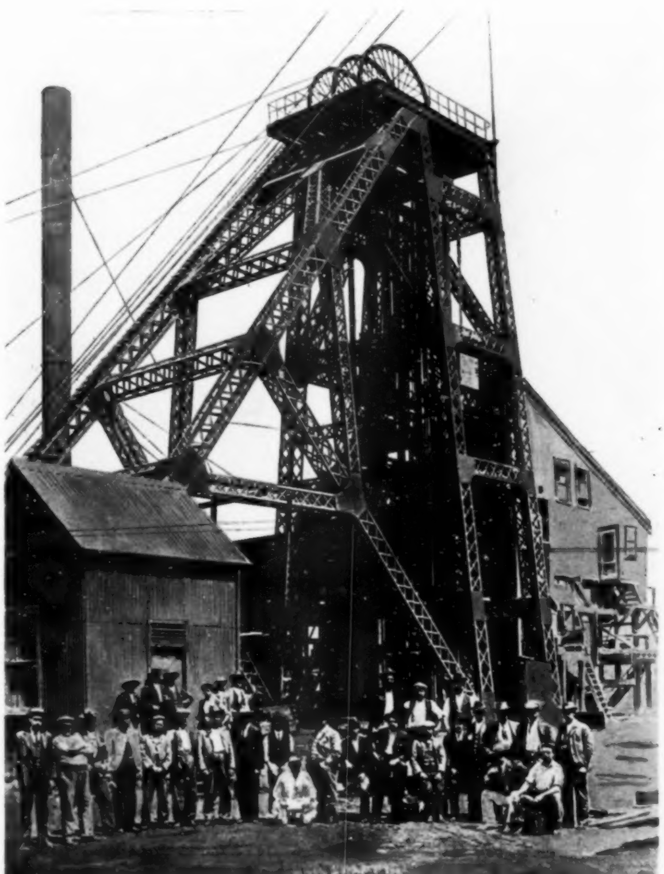
One of the most important applications of cold-drawn mild steel is in the form of bright-drawn bars for shafting, machining work, case-hardening, and shape wire, etc.

The second group includes all wire which is drawn for size and shape only and where the physical properties in the drawn condition are of very minor importance, the only requirement being sufficient softness to permit of machining or wire forming. Such wire falls under the general term of silver steel, but it includes alloy steels such as high-speed steel, tungsten steel, nickel and nickel-chrome steels, and certain varieties of stainless steels, all of which are subsequently hardened and tempered. Wire of this class is used for twist drills, taps, surgical and dental instruments, etc. Belonging to this group also, are such wires as needle wire, card wire, etc., although these are specialised branches of the industry.

The third, and perhaps most important, group is typified by rope wire and spring wire. These two types do not differ very greatly and there is certainly no definite line of demarcation between them. A good rope wire, for instance, is often the best wire for certain types of springs, and a good spring wire is the best wire for some ropes. But, in general, there are sufficient differences in properties and methods of manufacture between one and the other to necessitate a separate consideration of each.

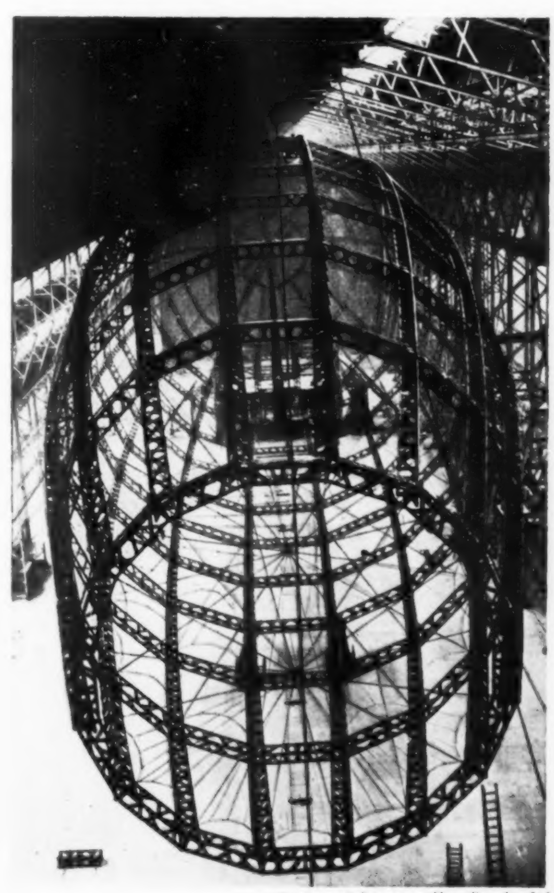
Wire springs are, of course, made from almost every conceivable variety of wire, and our first two groups also include spring wire, but spring wire of the high-tensile variety is made from hard-drawn, patented steel wire in various grades, according to quality, size, tensile strength and physical properties in general. Most spring wire of this class is made from the finest qualities of carbon steels available.

A typical pit-head, where steel winding ropes are necessary for the transport of the miners to and from the various levels in the mine and of the coal brought to the surface.



Courtesy of Bruntons (Musselburgh), Ltd.

Showing part of the airship R. 100 in which the structure was composed of Duralumin tubes and girders braced with steel wires and ropes.



Courtesy of Bruntons (Musselburgh), Ltd.

In general, the properties sought in high-grade spring wire are high elastic limit, more especially torsional elastic limit and high values for the limiting fatigue stress. Fortunately, the treatment necessary to obtain the optimum values in these properties is, in general, identical. There are some springs, however, where great toughness is essential and even more important than the abovementioned properties,—e.g., cycle saddle wire, and such wire more closely resembles rope wire.

Considerable tonnage of steel is also used for the less expensive spring wire used in upholstery. This wire is drawn from a water-quenched, mild steel wire. Another special wire of the spring-wire class is armature-binding wire which is supplied tinned to facilitate the soldering. This wire, which must be of a high tensile strength, must also be extremely tough to stand the winding operations, and only the highest grades of steel are suitable. An extra special variety of spring wire is piano wire, which is probably the highest grade of wire made.

The properties required of good rope wire are too complex to describe fully in a brief article. So many factors enter into the manufacture of wire, and so wide are the permissible variants in the operations involved that it is impossible to lay down any hard and fast rules governng either the methods of manufacture or the tests which the wire must stand. Only by a careful consideration of existing data and the almost intangible evidence which guides the practical man, can some approach to the problem be made. To enumerate the more important factors which influence the quality of a wire :

(1) The quality of the steel is probably the most important.
(2) Its composition in relation to its purpose.
(3) Its heat-treatment, which may be subdivided as follows : (*a*) temperature reached ; (*b*) time of heating ; (*c*) rate of cooling.
(4) Descaling or pickling operations.
(5) Drawing operations, which include the following :
  (*a*) Total reduction from rod.
  (*b*) Total reduction after final heat-treatment.
  (*c*) Stages of reduction or of programme of draughting.
  (*d*) Methods of drawing—i.e., single holing or continuous speed, wet or dry.

In addition to these factors influencing the wire itself, the problem is further complicated by the fact that the properties required in the rope wire are not definitely known or defined with accuracy, nor is it known with sufficient certainty how such properties as are known to be desirable can be neasured by means of tests on the wire. Further difficulties are the varieties of rope construction and the conditions of service. Thus, a wire which may have been found suitable for one rope of a certain construction may be quite unsuitable for another differently constructed, or in two identical ropes, wire which is suitable in one may be unsuitable in the other because the service conditions are totally different.

When the problems are thus stated they appear well nigh insoluble, and so, possibly, they are, in their entirety. Fortunately practical experience, which is always well ahead of exact scientific knowledge, or "absolute experience," enables us to use wire ropes daily with comparative safety.

While high tensile strength is desirable in most cases, and essential in many, its attainment involves some sacrifice of other important properties, and if due precautions are not taken the objects aimed at may be defeated. In this connection regard must be paid to the following points : the maximum tensile strengths permissible depend, among other things, on the diameter of the wire, the quality of the steel, and the particular application of the rope. A wire of 0.021-in. diameter with a tenacity of 120 tons per sq. in. is a very different thing from one of 0.128-in. diameter of the same relative strength. The former can be obtained without overdrawing, from a steel

containing only 0.40% carbon, while the latter requires, with the same amount of drawing, a carbon content of about 0.80%. Further, in the thicker wire, the use of special acid steel is almost essential if a wire of satisfactory quality is to be produced, while basic steel will generally be satisfactory for the thinner wire.

For standing rigging ropes and the like much higher strengths can be reached with safety when desired, but the tensile strength of such wire varies from 30 to 150 tons per sq. in., according to wire diameter and the requirements of the rope.

In every wire there is a maximum tensile strength which may be reached without appreciable sacrifice of other essential properties. Since the degree to which these other properties are essential varies, the permissible maximum tensile strength varies. In most running ropes, however, it may be taken that tenacities from 110 to 120 tons per sq. in. are seldom exceeded with advantage, and in many cases such wire is used where wire of lower strength would give better results, particularly in the thicker sizes.

Finally, one very special wire of the rope wire class is suspension-bridge wire, although in the construction of the large bridges, the wire is not fabricated in the form of a rope but is spun in parallel strands on the bridge itself.

Modern Tool Steels

(Continued from page 114)

which has given excellent results in service. This is primarily a tungsten steel. Another chisel steel, which is also suitable for many blacksmiths' tools, is one containing a percentage of nickel. The advantage of this steel is that it is more resistant to shock even than a good quality of carbon steel; it needs no tempering, and stands up admirably to its work, while the tool edge can be re-sharpened by simply touching it up with a sharp file. Another great advantage is toughness.

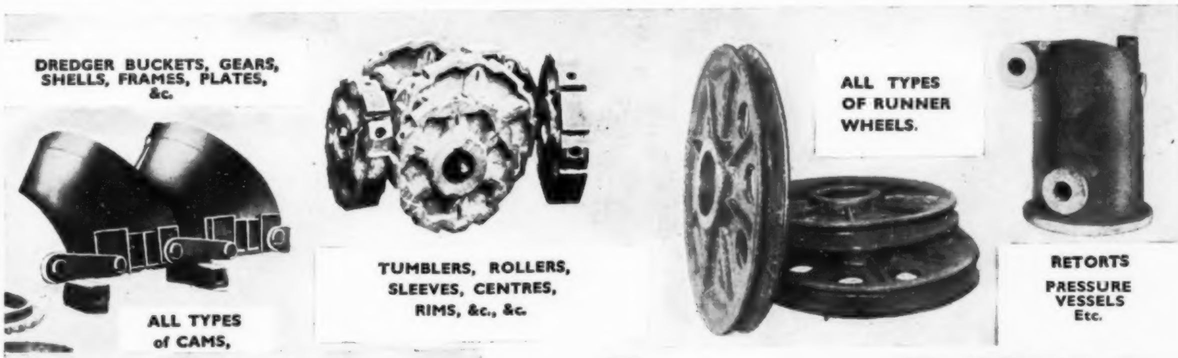
In a different category comes a special chromium-vanadium steel, designed for rivet snaps. While the uses of this steel are specialised and limited, it is, nevertheless, extremely valuable in view of the great extent to which riveting enters into modern construction. It is mainly designed for snaps used in connection with pneumatic hammers, and contains percentages of chromium and vanadium.

One could go on for some time enumerating these special alloy tool steels; but enough has been said to indicate how greatly the production of these materials has widened and spread during the past twenty years or more.

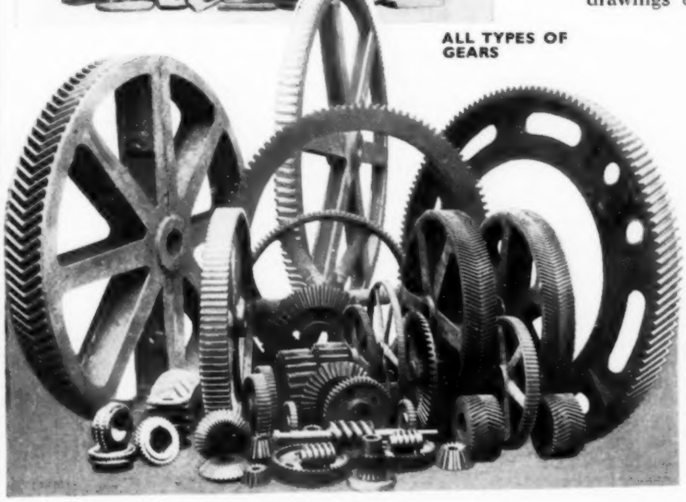
Carbon Tool Steels

A third great branch of tool steel production is the plain carbon tool steels. In composition and function these have not changed to any great extent. They are still used in large quantities today; but mainly for those purposes where conditions are not so severe, and speed and extent of output not the governing factors. In all, some five or six standard qualities are made, governed by the carbon percentage and temper, and suitable for many classes of tools, such as blacksmiths' tools, carpenters' tools, files, drills, chisels, punches, shear blades, saws, hammers, etc.

This article would not be complete without some reference to the tungsten-carbide cutting alloys which are now being made in Sheffield, and which, for cutting cast iron and non-ferrous materials, are even more effective than the super-high-speed steels. Tungsten-carbide is a sintered product. It is brazed in the form of a tip on to a mild steel shank. Remarkable results have been achieved with this material, and it can even be used on steel where a light skimming cut, as distinct from a heavy roughing cut, is required.


DREDGER BUCKETS, GEARS, SHELLS, FRAMES, PLATES, &c.
TUMBLERS, ROLLERS, SLEEVES, CENTRES, RIMS, &c., &c.
ALL TYPES OF RUNNER WHEELS.
RETORTS
PRESSURE VESSELS Etc.
ALL TYPES of CAMS,


PRESS TOOLS, DIES, TEMPLATES
PAN BOTTOMS—CHUTES, LINERS.
SCRAPER PLATES, &c.


ALL TYPES OF GEARS

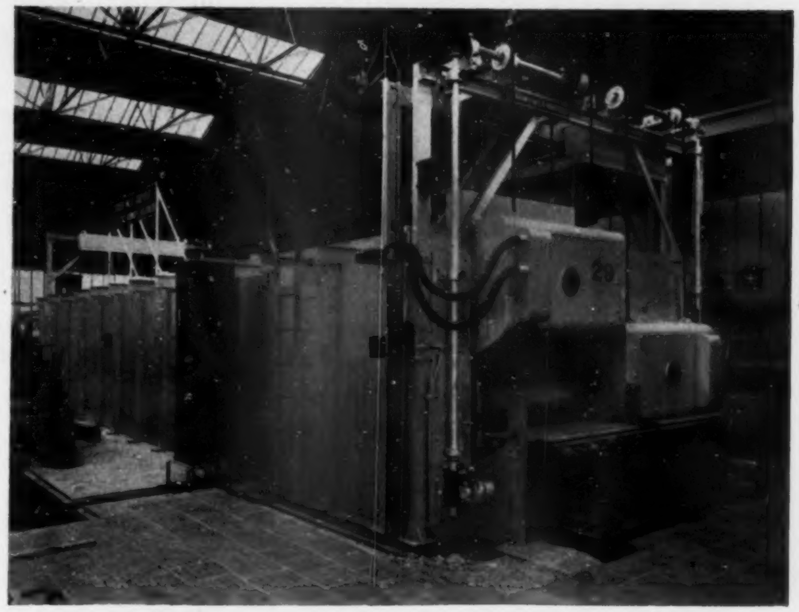

Dunelt

Recent Developments in Materials, Tools and Equipment

New Electric Billet Heating Furnace

A NEW billet-heating furnace for handling aluminium billets up to 20-in. diameter and 4 ft. long has recently been put into commission at the works of the Reynolds Tube Co., Ltd., which is claimed to be the largest of its type in the world. It is used in conjunction with a 5,000-ton extrusion press and the complete installation is capable of handling these large billets at the rate of four per hour. It is the fourth and largest furnace installed at these works by Messrs. G. W. B. Electric Furnaces Ltd. during the last years, and some fundamental considerations which led to its development were given by Dr. Lindner in the last issue of this journal.

The furnace is an electrically-operated pusher type and is complete with charging and discharging gear. It is rated at 600 kw., the heating units being located in three independently-controlled zones. The heating chamber is 39 ft. long, 9 ft. wide and 1 ft. 10 in. clear height above the hearth. Its total capacity is 40 billets, each 20-in. diameter and 4 ft. long, and weighing approximately 1,650 lb., and its output is four of these billets per hour. Air circulation is supplied by three patent centrifugal fans.



New electrically operated pusher type aluminium billet heating furnace of large dimensions.

Many pusher-type, billet furnaces are already in operation in this country, the design of which necessitates the use of shoes for conveying, in order to protect the surface of the billets. In this new design, the method developed is unique in that no unproductive weight is heated. Although this is also true of gravity-feed furnaces, the heat losses far exceed those of the special pusher, since side doors, which are the main cause of the additional loss, are necessary in the gravity type of furnace. Complete with the pusher mechanism, this furnace is regarded as the most economical and efficient yet designed for the purpose to which it is applied.

The design incorporates the Gibbons-Marchant pusher mechanism, which is already being used in continuous furnaces for the annealing of brass and copper components supported in trays. Two heat-resisting rods or tubes extend throughout the entire length of the furnace and are supported at intervals on open type " deadeye " bearings. Ears of a similar material are welded to the rods at the desired pitch, which coincides with the diameter of the billet plus the required clearance.

An ingenious mechanism, using a crank and lever gear for the longitudinal movement, is provided with means whereby the ears which are normally parallel to the hearth and clear of the billets, twist through an angle of 90° upwards at the beginning and end of the forward movement, thus conveying each billet one pitch forward with each stroke. The entrance door is mechanically interlocked with the twisting gear and ensures the door being clear before charging commences.

In addition to the conveying gear, a simple method of loading the charging table with billets from the floor level is introduced by using the same electric drive during the idle or return strokes of the pusher arms. The interlocked escapement-gear enables the charging end of the furnace to be controlled from the discharging end by the press operator without any attention, provided a sufficient number of billets are stocked on the inclined floor.

The charging mechanism includes a method already developed by Messrs. G. W. B. Electric Furnaces Ltd. on similar billet-heating furnaces. Each door, the hearth plate and tilting gear are interlocked and operated by an electrical drive, the push buttons being mounted on the furnace structure.

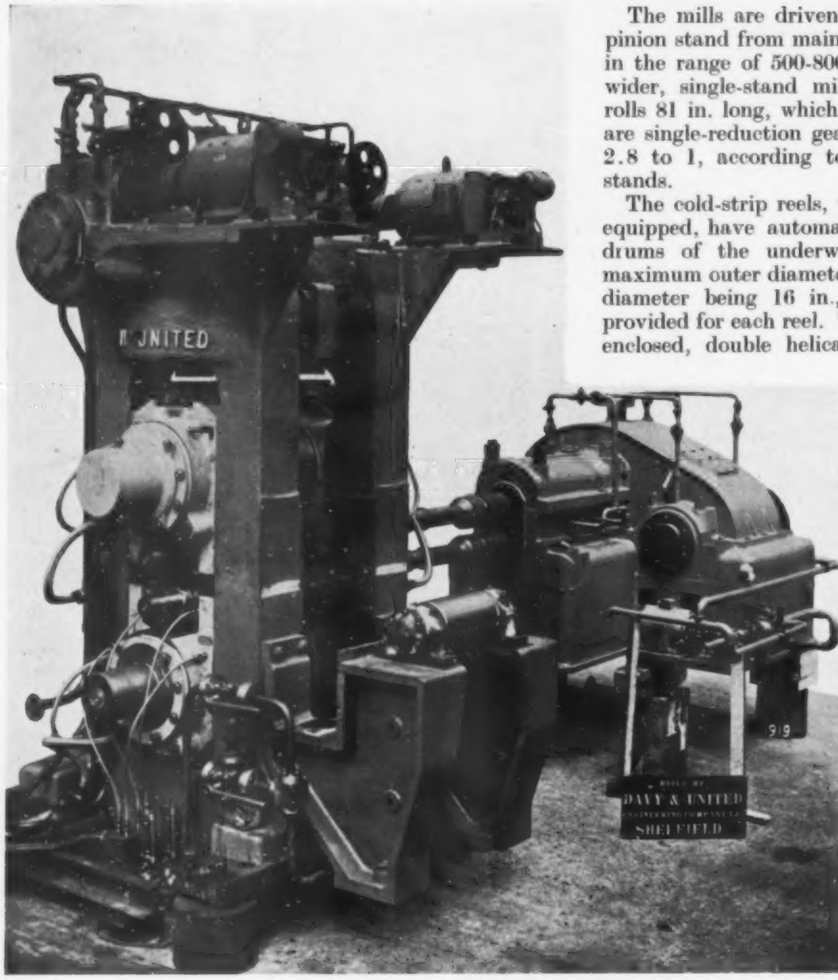
In order that billets 3 ft. to 4 ft. in length can be accommodated, the supporting and guiding beams inside the furnace are stepped to prevent side travel and risk of misalignment. To ensure absolute uniformity, the furnace is divided into three separately controlled zones and provided with Wild-Barfield patent centrifugal fans mounted on the roof structure.

The resistor elements, which are of strip design, are fitted in the roof and hearth only, a G.W.B. patent method of support being used in order that the maximum radiation factor and free circulation of air around the elements may be attained.

New Four-High Cold Strip Mill Plant

THE growing application of steel in strip form is making increasing demands on steel producers with the result that new rolling mill installations have been or shortly will be put into operation. A four-high cold rolling mill for this class of product is under construction at the Darnall Works of Davy & United Engineering Co., Ltd.

The new plant embraces many interesting features which contribute to the present trend for high rolling speeds with increased accuracy of dimensions and finish. It comprises a four-stand continuous mill, having rolls 7½ in. diameter and 18 in. diameter by 14 in. long ; one single straight-away stand, having rolls 8 in. diameter and 20 in. diameter by 18 in. long ; and a single straight-away stand having rolls 7½ in. diameter and 18 in. diameter by 14 in. long. The four-stand continuous mill is so arranged



One of the stands of a new four-high cold strip mill plant nearing completion.

that it can be used as a four-stand tandem, or a three-stand tandem and one single stand, and is, therefore, equipped with a reel following the third stand and a reel following the fourth stand. In addition, each of the single stands is equipped with a reel.

The mills are designed to roll steel strip in widths up to a maximum of 14 in. down to the finest cold-rolled gauges, at a rolling speed from 350 to 700 ft. per minute. All are equipped with two motor-operated screwdown gear and the movement of each screw is indicated on a producto-meter operated by Selsyn transmitter and receiver. Control is by push button conveniently located on the working side of each mill.

The work rolls and the back-up rolls are of special forged steel, the former being equipped with dual taper-roller bearings and the latter with Morgoil fully enclosed, oil-film, roll-neck bearings. An oil-supply equipment will be provided for serving all stands, while a self-contained, oil-pressure accumulator system is provided for power balancing of both work and back-up rolls. The arrangement is such as to reduce the possibility of wear to an insignificant factor and provides for very efficient operation. In addition, provision is made for spraying the rolls with soluble oil-coolant which is supplied from a coolant system serving all stands.

The third and fourth stands of the tandem mill and both single-stand mills will be equipped with flying micrometers on the outgoing side. All stands are equipped with spring-tensioned, roll wipers, while the first and last of the tandem mills and the two single-stand mills are equipped on the ingoing side with felt-lined, strip wipers.

The mills are driven through a combination drive and pinion stand from main mill-motors of 250 h.p. with speed in the range of 500-800 r.p.m., except in the case of the wider, single-stand mill with 8-in. and 20-in. diameter rolls 81 in. long, which has a 400-h.p. motor. The drives are single-reduction gear with ratios varying from 1.8 to 2.8 to 1, according to the required speeds at the mill stands.

The cold-strip reels, with which some of the stands are equipped, have automatically expanding and contracting drums of the underwinding, non-marking type. The maximum outer diameter of the coil is 45 in., the reel-drum diameter being 16 in., and air-operated stripper-gear is provided for each reel. The drive for these reels is a totally enclosed, double helical gear-unit, equipped with roller bearings and driven from a motor of 60 h.p. at 300-1200 r.p.m. with constant tension-regulator.

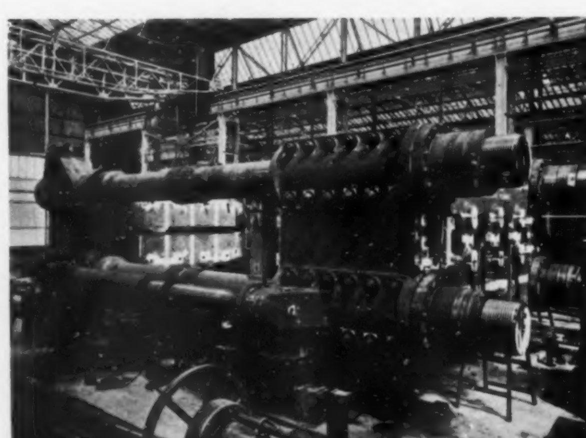
Bending and Forging Presses

TWO of the largest presses ever constructed are in course of manufacture at the works of Davy & United Engineering Co., Ltd. One is a 12,000-ton forging press and the other a 15,000-ton bending press. The former is of the four-column, steam hydraulic-intensifier type and is capable of forging a hollow drum, 19-ft. diameter by 20 ft. long. In view of the enormous size, the entabulature or top-head of this press and the baseplate are built up of heavy steel girders, strongly bolted and keyed together, and the baseplate has two extension girders on each side, to which the bed plates of the manipulating gear are attached.

Some idea of the size of this forging press is gathered from the weight of steel castings used in its construction; the entabulature, for instance, which comprises six girder castings, has a total weight of 310 tons, while the baseplate, composed of fifteen castings, weighs approximately 530 tons. The manipulating gear is hydraulically operated and the press is also equipped with hydraulic, tool-changing gear and hydraulic gear for handling slab ingots under the

(Continued on page 123)

15,000-ton binding press partly erected and lying on its side.



Trends in the Development of Alloy Steels*

By Ed. Houdremont

Attention is directed to the trend of alloy-steel development in Germany. The author refers particularly to structural steels, tool steels, stainless and heat-resisting steels, ar.d to special-purpose steels emphasising the need for adding exact quantities of particula alloys in order to obtain desirable qualities, such qualities to be measurable according to service requirements.

THE term "alloy steel" should be used only for products to which has been added exact quantities of certain alloys previously determined in order to obtain such qualities as are necessary for the purpose in question. These qualities must be measurable, and the measures should be on a certain relation to the capacity of the steel to stand its test in practice—i.e., to be useful for special demands. As this relation is not always completely clear and further correct testing methods are at present unknown, the development of alloy steels has not always taken a straight line; sometimes it was necessary to go back a step, when experience showed that the tests did not give the correct measure of capacity as was anticipated. With these views in mind the author considered the development of structural steels, tool steels, stainless and heat-resisting steels, and steels with special physical properties.

TABLE I. MECHANICAL AND MAGNETIC PROPERTIES OF ARMATURE BODIES OF ELECTRICAL MACHINES.

Nature of the Steel.	Yield Point, kg./mm². (Tons/sq. in.)	Tensile Strength, kg./mm². (Tons/sq. in.)	Elongation (Length of Testpiece =5×dia.) %	Induction	
				at A.W./cm.	Gauss.
Unalloyed	27 (17)	50 to 60 (32 to 38)	20	25	13800
Nickel steel (1 to 2% Ni)	35 (22)	60 to 70 (38 to 45)	18	50	15800
Chrome-nickel steel, and since 1928 chrome-nickel molybdenum steel	45* (28·5)	65 to 75 (41 to 78)	16	100	17300
	50† (32)	65 to 80 (41 to 51)	15	200	18800
	60‡ (38)	75 to 90 (48 to 57)	12	300	19600

* Asked for since 1926 to great extent.
† First produced 1935.
‡ First inquiry for steel of 70 kg./mm². (45 tons/sq. in.) in 1935.

Structural Steels

Table 1 can be considered as significant of the original development of structural steels. It gives figures for armature-bodies of electrical machines—i.e., parts of machines which are subjected to a comparatively static load, in this case, centrifugal force. Much more numerous, however, are the cases of fluctuating—i.e., repeating or alternating stress by bending as well as by twisting forces, or by both kinds of forces simultaneously. Here the testing methods are not so much in direct relation to the actual working conditions in practice; the result was a discontinuous development as perhaps is signified by Table 2, giving figures for aircraft crankshafts. Reasons for lowering the tensile strength in recent years are given: these include greater difficulties when machining the shafts, increase of crystallic segregations with steels of higher tensile strength and subsequently a much lower reduction of area and elongation in transverse than in longitudinal direction. Decisive, however, were notched bar impact tests which showed that steel of high tensile strength gave only small and sometimes even no advantages against steel of lower tensile strength. This led to the view that the use of valuable steel can only be recommended for very carefully designed parts of machines where notches, etc., have been avoided. Thus, in recent years, there has been a tendency to revert to steels of high strength of 200 kg/mm² (127 tons 1 sq. in.), and more; but great care must be taken that they are hardened throughout, otherwise a high tensile strength with an insufficient resistance to alternating stress may result. A favourable effect can be expected for steels of such high tensile strength by case-hardening or nitriding the surface, a fact which may have a considerable influence on the further development.

TABLE II.
DEVELOPMENT OF THE MECHANICAL PROPERTIES OF CRANK-SHAFTS OF AIRCRAFT.

Nature of the Steels. * (The steels with comparatively low percentage of material which has to be imported into Germany.)	Yield Point, kg./mm² (Tons/sq. in.)	Tensile Strength, kg./mm² (Tons/sq. in.)	Elongation Length of Testpiece =5×dia. %	Reduction of Area, %	†Notched Bar Impact Value, mkg./mm² (Ft./lb. per sq. in.)
HEAT-TREATED (HARDENED AND TEMPERED) CRANKSHAFTS.					
Chrome-nickel steels (1908/1913)	60 (38)	75 (48)	20	65	24 (27)
Chrome-nickel steels (1908/1913)	80 (51)	95 (60)	15	55	18 (20)
Chrome-nickel steels (1913/1925)	90 (57)	110 (70)	12	45	12 (13·5)
Chrome-nickel-tungsten steel (1913/1920)	115 (73)	125—135 (79—85)	10	40	10 (11·2)
Chrome-nickel-molybdenum-vanadium steel (1929)	134 (85)	160 (102)	10	33	4—5 (4·5—5·6)
Chrome-nickel-molybdenum steel (1932)	115 (73)	120—130 (76—82)	12	45	—
*Chrome-molybdenum-vanadium steel (1933)	90 (57)	110—115 (70—73)	14—10	45	—
*Chrome-nickel-molybdenum-vanadium steel (1933)	95 (60)	105—120 (66—76)	16—12	50	—
CASE-HARDENED CRANKSHAFTS.					
Chrome-nickel-tungsten steel (1924)	85—95 (57—60)	130—155 (82.5-98·5)	14—10	50	14—10 (15·7-11·2)
Chrome-nickel-tungsten steel (1930/1931)	75—85 (48—54)	115—130 (73—82·5)	16—12	50	—
*Chrome-nickel-molybdenum steel (1934)	75—85 (48—54)	115—130 (73—82·5)	16—12	50	—

† Testpiece 30 × 30 × 160 mm³ ($1\frac{3}{16}$ in. × $1\frac{3}{16}$ in. × $6\frac{5}{16}$ in.) with a notch of 15 mm. ($\frac{19}{32}$ in.) depth and 4 mm. ($\frac{5}{32}$ in.) diameter.

Steels for low temperatures are chosen according to notched-bar impact tests, as toughness is the decisive quality of such steels; but again the problem is to adapt these tests to the actual working conditions in such a way that the test results can be used as a real measure of service conditions, as published investigations have shown how much these results vary with the form of the test piece.

A very important development has taken place in recent years with steels working at high temperatures. The hot tensile test was the first testing method for such cases, but it was found that the results did not agree with the actual behaviour of the steels in practice. As tests more adapted to the actual conditions of the practice would take too much time, short-time methods have been developed for the determination of the creep resistance, and astonishing success has been obtained, as Figure 1 may show without further explanation. Unfortunately, however, another phenomenon took place which necessitates great care when using these steels: after some time,

* Extract of a Paper before the Annual Meeting of the Verein deutscher Eisenhüttenleute. *Technische Mitteilungen Krupp*, May, 1939.

fractures occurred with small deformation and very low reduction of area. An explanation of this phenomenon is not yet available, it can only be recommended to study carefully the forces and times in practice, and to adapt the design and the steel quality for these parts of machines to the working conditions, as far as possible, according to our present knowledge.

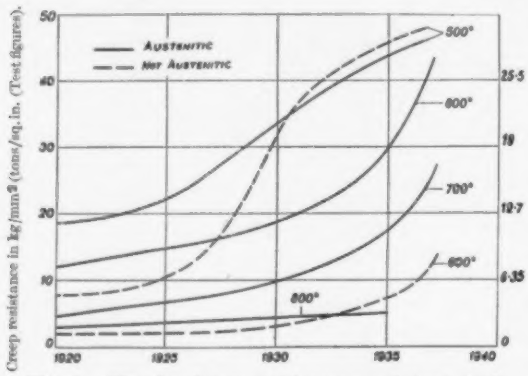


Fig. 1.—The development of creep-resistant steels.

The considerations on constructional steels may be summarised as follows: the development was not always continuous. It was determined by the demands of the customers. The knowledge of the effect of the alloys on the qualities of the steel could be used directly in practice only where the conditions of load were simple and well known, so that their relations to the qualities of the steel could be easily established. In many cases, however, these conditions are not yet known, it must, therefore, be expected that the development may also be discontinuous in future if no tests can be developed which reflect working conditions better than the methods at present in use. This may be illustrated by the example of armour plate which is subjected to practical tests, such that discrepancy of behaviour is unlikely. For all other cases in which constructional steels are used, it must be said that tests which have a sufficient similarity to practice take too much time. Here, the best help to development is a modern and improved design of the machine parts and the collection of experience on such parts in which the designer and metallurgist should co-operate.

Tool Steels

Quite different from the development of the constructional steels is that of the tool steels. The basis here is not a special test for a certain chemical or physical property, but the cutting test, which is very similar to the working

	C %	Cr %	W %	Mo %	V %
Before 1925	0·75	3·8	18	—	—
	0·75	4·2	18	—	1·0
	0·85	4·2	20/22	0·8	1·5
	0·80	4·2	25	0·8	1·5
Since 1924/26	0·85	4·2	14	—	2·2
Since 1934/35	0·80	4·2	5/6	4/5	2·2
Since 1936/37	0·75	4·2	11	0·5	0·9
	0·80	4·2	11	0·7	1·4
	0·85	4·2	12	0·7	2·5
	1·0	4·2	—	3·4	2·8
	1·0	4·2	2·1	3·1	2·1
	0·7	4·2	2·0	8·0	1·0

Fig. 2.—Cutting capacity and alloy contents of high speed tool steels. Chrome nickel steel of 100 kg/mm²(63.5 tons) sq. in.) tensile strength has been machined with a feed of 1.4 mm (0.06 in.) per rev. and depth of cut 5 mm. (0.2 in.)

of the steel in practice. Fortunately, these tests do not take so long that they cannot be carried out in a laboratory where this seems to be useful.

The general development of high-speed tool steels may be illustrated by Figure 2; but it must be taken into account that, say, since 1935, the use of foreign alloys had to be limited in Germany as far as possible, a factor of great influence. As with high-speed tool steels, the development of the cutting metals, stellite and carbide cutting alloys, is based on the test in practice. How important the increase in cutting capacity of these modern cutting materials against carbon steel and even high-speed steel, is shown in Figure 3.

Stainless and Heat-resisting Steels

The development of these steels is not conceivable without extensive scientific research work in the laboratory.

TABLE III.
DEVELOPMENT OF STAINLESS (CORROSION- AND ACID-RESISTING) STEELS AND CASTING ALLOYS.

Approximate Year of Production.	Country of Production.	Analysis.				Structure.	Workability.	Resistance Against. (+ = resisting; (+) = conditionally resisting; — = not resisting.)					Safety Against Intercrystalline Corrosion.
		% C Approx.	% Cr Approx.	% Ni Approx.	Other Additions.			Corrosion.	HNO_3.	H_2SO_7	H_2SO_3.	HCl.	
1898	Germany	—	100	—	—	Ferritic	Casting	+					
1906/08	France	0·50	—	—	15/20 Si	Ferritic	Casting			+		(+)	
1911	England	—	40	—	—	Ferritic	Casting		+				
1912/13	Germany	0·2/0·3	20/22	5/7	—	Austenitic	Malleable	+	+				No
		0·2	12	2·5	—	Martensitic	Malleable	+					,,
1915	England	0·5	13	—	—	Martensitic	Malleable	+					,,
1920	England	0·1	16	—	—	Ferritic	Malleable	+	+				,,
1922/26	Germany	0·1	18	8	Mo	Austenitic	Malleable				+		,,
1925	Germany	18 Cr/8 Ni plated on carbon steel											
1927/28	Germany	<0·07	18	8	—	Austenitic	Malleable	+	+				Yes
1928/29	Germany	0·1	18	8	Ti, V, Ta, Nb	Austenitic	Malleable	+	+				,,
1931	Germany	<0·07	18	18	Mo + Cu	Austenitic	Malleable			(+)		(+)	,,
1928/34	Germany	0·1	18	(2 Mo)	Ti, Ta, Nb	Ferritic	Malleable	+	+				,,
1930/34	U.S.A. and Germany	0·1	18/9	8/18 Mn	(Ti, Ta, Nb)	Austenitic and Ferritic	Malleable	(+)	(+)		(+)		,,
1937	Germany	0·1	15	30	Sb	Austenitic	Casting					(+)	Conditionally
1937	Germany	0·1	55 Cu	40	Sb	Austenitic	Casting			+			Conditionally

TABLE IV. DEVELOPMENT OF HEAT-RESISTING STEELS.

Approximate Year when		Analysis.						Additional Elements	Structure.	Workability.	Weldable.	Toughness.	Behaviour at High Temperatures.		
First Mentioned.	Introduced.	% C.	% Si.	% Mn.	% Cr.	% Ni.	% Al.						Scaleproof to °C.	Sulphur-proof.	Heat-Resisting.
1902/06	1906/10	0·1/0·5	—	—	10/20	30/80	—	—	Austenitic	Malleable (Wire)	Yes	Good	1100/1250	No	Very good
1900/13	1911/20	0·1/2·0	0·5/4·5	—	3·40	—	—	(Mo)	Ferritic Carbidic Martensitic	Casting and Malleable	No	Partly brittle if cold	700/1200	Yes	Moderate
—	1917/21	Surface coatings (Al and Cr–Ni)								Brittle surface	No	—	950	Yes	—
1917	1921	—	—	0·10	0·10	—	14/16	—	Ferritic	Casting and Malleable	No.	Comparatively brittle if cold	1100	Yes	—
1921/29	1922/29	0·1/0·3	1·5/3·0	—	15/25	8/20	—	(Ti, W)	Austenitic	Malleable	Yes	—	900/1200	Partly	Very good
1925		Plated													
1917/23	1930	<0·2	0·5/4	—	15/40	—	2/8	(Co, Mo)	Ferritic	Malleable (Wire)	Yes	Brittle if cold	1000/1350	Yes	Moderate
		<0·2	0·5/2·5	—	0/12	—	0·4/3	(Mo)	Martensitic Ferritic	Malleable	Yes	Partly brittle if cold	600/1000	Partly	Moderate
1919/35	1935/36	0·3	0·3	5/25	10/45	(+)	(+)	Ti, W	Partly Austenitic	Malleable	Yes	Brittle if cold	900/1100	Yes	Good
		0·3	3/10	15/30	<10	(+)	(+)	W, Ti	Austenitic	Malleable	Yes	Partly brittle if cold	950	Yes	Good

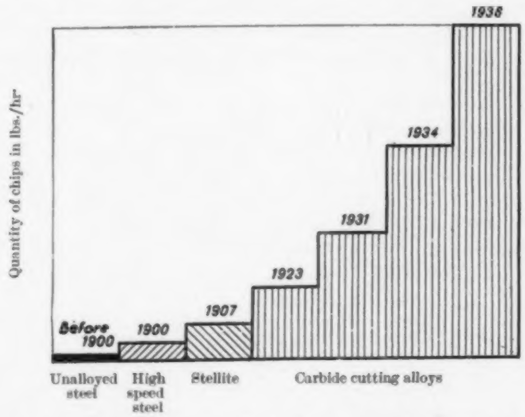


Fig. 3—Progress in tool steel during the period 1900 to 1938.

The result is a continuity from the start to the present state, which is not interrupted as with the constructional steels by fluctual movements backwards and forwards. Again a survey will best be obtained by data given in Tables 3 and 4.

Steels with special physical properties

Perhaps a unique part of the technique with these steels is discussed : here, the consumer or the physicist informs the producer of the material from the start which properties are really necessary and important for its application in practice. Parallel with this demand, the information is given how these properties can be measured and, according to our present knowledge, how the delivered material can be expected to agree with these demands. The result of these facts provided very steady development and accorded to scientific principles which always coincided with practical experience.

There seems, however, a tendency to develop in a new direction the science of steel, and perhaps, when our knowledge and experience is more advanced than at present, it may be possible to explain the behaviour of the alloys in the steel from peculiarities of the structure of the crystals and even of the single atom, and to come to a quantitative calculation in advance of certain properties of a new material, which are asked for a certain purpose.

One realises it is a long view into a possible future to which the author gives an interesting hint ; although he has, in the course of his explanations, pointed out that theoretical considerations and tests in the laboratories must always be supplemented, and even sometimes replaced, by tests which correspond to working conditions in practice. In his concluding remarks, he emphasises the necessity for further scientific research to maintain development in the production of steels.

Aluminium Rollers for Printing

A GERMAN development in the use of aluminium is that of using an Al-Mg-Zn alloy (Okudal) for printing wallpapers. In that country, it is stated, brass cylinders or rollers have been used for that purpose for more than ten years, but the cylinders of aluminium alloy have been found to be equally satisfactory as regards printing qualities and longevity, whilst the reduction in weight is a considerable advantage. One such roller is claimed to have printed 2,711,047 metres of wallpaper and still show no signs of wear or reduction of the pattern or relief printing surface. The advantage, of course, has been recognised and used in other countries and savings of 68% weight have been reported. This alloy has been used both for rotary letterpress and gravure printing ; there seems no reason why its application should not be further extended and include textile printing.

Recent Developments in Material Tools and Equipment

(Continued from page 120)

press without the use of cranes. The press is driven by four steam, hydraulic intensifiers of "Davy-United" latest type, and the auxiliary cylinders are operated from an accumulator system consisting of electrically-driven pumps and air-loaded, hydraulic accumulator.

The bending press is of the bottom-cylinder, vertical type and the top-head can be adjusted to vary the daylight by means of electrically-driven gearing. In this case, also, the entabulature and baseplate of the press are built up of heavy steel girders, the total weight of the castings in these two structures being nearly 600 tons.

Four jack rams, working in cylinders carried in the baseplate, are provided for adjusting the plate during bending and the press is provided with manipulating and tool-changing gear. The operation of the press is effected by means of two sets of hydraulic pumps, and the auxiliary cylinders are worked from an accumulator system comprising electrically-driven pumps and air-loaded accumulator.

It is gratifying that presses of this type and size are designed and built in this country, and we hope at a future date to give more detailed particulars of these machines.

Steel in the Automobile and Aeronautical Industries

(*Continued from page* 108)

essentially used as spring steels, whilst the nickel-chromium and the nickel-chromium-vanadium steels are employed for high duty members, such as highly stressed connecting rods and crank shafts. For gears, where strength and toughness combined with resistance to wear is demanded, there is choice between the nickel-chromium steel of the air-hardening type, giving over 100 tons per square inch tensile strength, and the slightly lower tensile materials to which surface hardness is given by case-hardening. For parts of highest hardness, such as parts of ball-bearings, the carbon-chromium steel is largely employed.

In connection with the requirements for wear resistance, the development of steels which can be surface hardened by nitriding has been a special advantage; particularly as in the final surface hardening treatment these steels do not suffer from any appreciable distortion, which is a disability of the other method of obtaining hard surfaces. These steels have superior hardness and wear-resisting properties, and are subject only to the limitation that they should not be employed where extremely high loading is concentrated on small areas.

As will be seen from Table II, the stainless steels now available can be put into service with a wide range of mechanical properties. The so-called stainless iron and the stainless steel have proved their usefulness in corrosion-resisting properties, but are surpassed in their degree of resistance to corrosion by the austenitic chromium nickel steels. The 18% chromium/2% nickel type of steel is practically resistant to sea water, whilst the 18% chromium/8% nickel type is completely resistant if the surfaces are kept reasonably free from deposits. For aeroplane parts and more particularly for seaplanes, the extra resistance to corrosion is of direct importance. The demands made on materials for aircraft purposes include a combination of stainless properties with very enhanced mechanical properties. A high proof stress is called for as well as substantial ductility, permitting severe bending and forming operations without fracture. Consequently, the production of stainless material in strip and bar form has been developed. The final mechanical properties can be obtained in two ways, either by heat-treatment or cold-working. In the case of the 14% chromium steels the high tensile properties are obtained by hardening and tempering, but the austenitic chromium nickel steels are not amenable to hardening and tempering by thermal treatment. They can, however, be given substantial mechanical strength associated with a high degree of ductility by cold rolling.

Reference has already been made to the importance of the materials employed being amenable to fabrication processes. Amongst these processes can be included melting, casting and hot manipulation in the hands of the steelmaker, heat-treatment, machining, pressing and shaping, hot or cold, and welding.

Choice of material is in numerous cases decided on the basis of their response to these operations. In connection with the last item, welding, it may be said that increased use is now made of this method of construction, and there is now a better understanding of the technical processes involved and their effects on the materials. It is important, not only that good joints should be made, but also that the welding operation should not produce deterioration in the parts of the metal adjacent to the joint. It was in answer to the problem of such deterioration in connection with the 18/8 chromium-nickel steels that special modifications of such steels have been devised which are free from the disability which has been described as "weld-decay." A special test for resistance of such materials to intercrystalline corrosion is one of the standard tests incorporated in the Air Ministry specifications.

Perhaps no part of a motor-car or aeroplane is more important than the engine valve, whether it be of the poppet or of the new sleeve valve type. Much energy has been devoted to overcoming valve troubles, and it is some satisfaction to note that the latest type of heat-resisting steels devised for these parts are satisfactorily performing the onerous duties imposed both from the point of view of retention of strength at high temperatures and of resistance to oxidation.

In conclusion, it should be said that progress in the aero and auto world is very rapid and developments are still taking place as regards improved materials, treatment and design. The high achievements already effected may quickly prove to be themselves surpassed.

A.S.T.M. Specifications for Pipe and Piping Materials for High-Temperature and High-Pressure Services

This 135-page publication contains eighteen specifications covering carbon steel and alloy steel pipe and tubing, castings, forgings and bolting. A large number of standards have been published separately by Committee A-1 of the American Society for Testing Materials, and that Committee has been busy for some years on the development of specifications for steel materials for high-temperature service.

The specifications given have been used extensively, and a number have been approved as American standarsd. The eighteen are:—cover pipe and tubing, steel castings, forgings and alloy steel bolting material.

Copies of this 135-page publication, heavy paperboard cover, spiral ring binding, can be obtained from A.S.T.M. Headquarters, 260, S. Broad Street, Philadelphia, Pa., U.S.A., at $1.25 per copy.

Steels for Power Plant

(*Continued from page* 113)

It will be seen that there is only a very slight difference between the properties of the core and the ends of the barrel itself.

There are, however, many applications for which rather lower mechanical tests are satisfactory, and where it is necessary, for example, to obtain figures throughout the rotor which are rather better than the requirements of B.E.A.M.A. Grade III, the writer's firm have found that a steel containing about 0·4 %of carbon and 2% of nickel gives most excellent results, the tests obtainable being approximately as follows:—

Yield Point:	Tangential and Radial......	23 to 26 tins/sq. in.
Maximum Stress:	Tangential	to 42 tons/sq. in.
	Radial	to 45 tons/sq. in.
Elongation and Bend:	In accordance with B.E.A.M.A. III.	

Core Properties

Yield Point	21 to 25 tons/sq. in.
Maximum Stress	38 to 44 ,,
Elongation (average) ..	18%

It has been found recently as the result of numerous experiments that the properties of this nickel steel, especially the ratio of yield point to maxium stress, can be greatly increased by the addition of quite a small quantity of vanadium, and the following tests have already been obtained:—

Yield Point (Longitudinal, Tangential and Radial	30 tons/sq. in.
Maximum Stress	45 ,,
Elongation (Radial and Tangential)............	17%
Elongation (Longitudinal)	22%
All Bends	180°

It should be noted that these are actual test figures, and are not derived from any specification. They are given merely to illustrate the order of the properties obtainable from the steel in question.

The Use of Steel in Heavy Works Plant

By W. Reid

Managing Director, Davy and United Engineering Co., Ltd.

The successful operation of plant and machinery is dependent to a large degree on the use of steel in their construction; the particular grades of steel used vary according to service requirements. In this article reference is made to heavy works plant for which the author states there is a growing tendency to use steel in order to obtain the utmost reliability over a long period.

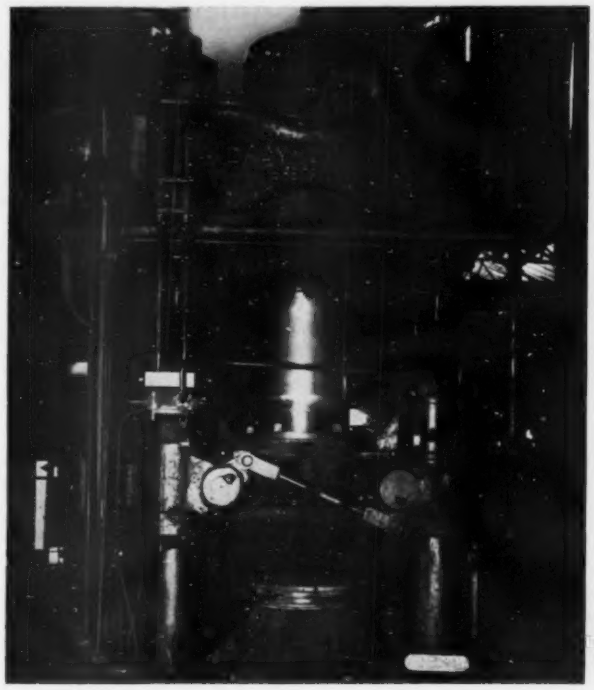
THE use of steel in heavy plant for steel works and other trades may be surveyed from various points of view. In the first place it is, of course, well known that steel is essential for various parts of machines due to the stresses to which they are subjected but this accounts only partly for the amount of steel used at the present time. In explanation of this statement it can be said that in the construction of heavy plant there has been a growing tendency in recent years to employ steel instead of cast iron, even though the latter is sufficiently strong for the duty, in order to obtain the utmost reliability over a long period. In modern conditions, where maximum production is required, it will be readily understood that it is essential for stoppages in the working of plant to be reduced to the absolute miminum, not only because such stoppages may cause serious difficulties in the handling of the partly-finished product, but also on account of the losses in charges of various kinds caused by interruption of output.

The accompanying illustration shows a modern 2,500-ton wheel-forging press recently installed at a Sheffield works. The improvements which have been made in the design of such presses have resulted in very high speeds of working, permitting of high outputs which call for great resistance in the materials employed for the press parts. The press itself is of practically all-steel construction, this material being employed for the entablature or top head, the base, the main cylinder, the moving crosshead, the lifting cylinders and, of course, the columns and nuts. In the case of large presses, steel castings of more than100 tons individual weight and forged steel columns approaching this figure are being employed. Parts of such a press are illustrated elsewhere in this journal.

Again, in the case of steam hammers, particularly those which are used for cogging down special steels, the standards are frequently made of cast steel, instead of cast iron as in the past, as experience has shown that the extra reliability and longer life are well worth the cost.

The same conditions have obtained in the construction of rolling mills and whilst there are, of course, many parts of rolling-mill auxiliaries for which cast iron is perfectly satisfactory, steel has taken its place almost entirely in large mill trains and in the principal accessory machinery. The pinion housings of heavy rolling mills, particularly in the U.S.A., are now often made in cast steel instead of cast iron and in the case of rolling mills for large structural sections in which the roll housings were previously made in cast iron, such housings are generally made of cast steel for new installations. Hydraulic cylinders for auxiliary equipment of rolling mills which were of cast iron are now almost invariably made of steel.

Cold steel strip rolling mills of the four-high type have roll housings of cast steel whereas such housings in the case of the older type of two-high mills are cast iron. The latter mills also have cast-iron rolls but the work rolls of four-high mills are made of forged steel. An illustration of one stand of a four-stand, four-high continuous, cold steel-strip mill which is built almost entirely of steel is shown on page 120 of this issue. In modern practice roll housings are of cast steel made very heavy for rigidity, the chocks or bearing casings for the roll necks are of forged steel in the case of the work rolls and cast steel for the backing rolls, and the rolls are of forged steel hardened and ground. The driving spindles are of specially-forged steel and the combination pinion and drive box are of fabricated, welded-steel construction.



A modern 25,000 ton wheel forging press, recently installed at a Sheffield works.

A notable recent example of the extended use of steel is the adoption of fabricated welded construction in place of cast iron for such equipment as hydraulic pump frames, bedplates for motors and machines, large gear wheels, etc. Due to the great progress made in recent years in welding practice, this type of construction has proved perfectly satisfactory, providing a rigid assembly of great strength. Moreover, fabricated welded structures can be more quickly manufactured than large castings for which patterns are required and the time taken up in the making of the pattern and for cooling, fettling, etc. is considerable. This type of construction is now being employed for many different machine parts, including roller tables for heavy rolling mills, and frames for large shearing machines are frequently made of fabricated construction.

In addition, there is a very wide field of application of special steels in the construction of heavy works plant, where the parts are highly stressed or where the duty is of a very severe nature, as in the case of many modern installations in which the mechanical handling of the product permits of continuous operation of the plant. Instances of this kind include the making of cylinders and columns of large forging presses in nickel steel. The same material is employed for highly-stressed connecting bolts which secure the parts of press heads and baseplates together.

In the case of hydraulic pumps, it is now common practice to make the pump rams and also the valves and

seats in stainless steel which is found to give extremely long life to these parts which are subject to corrosion due to contact with the water. Special steel is also employed extensively in the manufacture of gear pinions for reduction gearing for rolling mill drives and other purposes where such parts are highly stressed, the material generally employed being nickel steel, although a number of other alloy steels are also used.

In a short article it is impossible to give details of many other instances of the extended use of steel, but sufficient has been said to indicate the wider employment of this material in recent years.

Application of Alloy Cast Irons to Crushing and Grinding Machines

By L. Sanderson

Alloy cast irons for crushing and grinding machinery are briefly discussed. Attention is directed to nickel, nickel-chromium, nickel-chromium-molybdenum, copper-chromium-molybdenum and vanadium. Cast iron alloys and some service results are given.

A MARKED characteristic of recent metallurgical development is the application of alloy cast irons to crushing and grinding machinery construction. For this reason, a brief survey of the different current types of alloy irons, with their specialised uses in this field, and an indication of the results achieved, may be of value and interest.

Probably the most widely used of these irons is a nickel-alloy, cast iron manufactured by a special process, and used primarily in casting form. It is dense in structure and extremely tough, which enables it to offer a high degree of resistance to wear. It can be machined without difficulty, and as cast, has a tensile strength of approximately 23 tons per sq. in., which can be increased by suitable heat-treatment, to 30 tons and more, 35 tons being probably the highest figure attainable. The Brinell hardness number is 250 for " as cast " metal, and 400 for the heat-treated material, but these are only average figures. The method of heat-treatment is to quench in oil from 850° C., and then temper at 300–500° C., the exact temperature varying with the tensile strength demanded.

This alloy has to withstand heavy duty, and by its employment, design can be made more simple, while severer stresses can be withstood than ordinary cast iron is capable of resisting. Typical uses are crusher frames, pulleys, sheaves, hoist drums, and the like. The excellent impact strength, fatigue resistance and power of resisting heavy stresses, have enabled this material to replace steel castings and forgings in certain instances.

A second alloy iron of the cast type has an analysis comprising approximately 14% nickel, 6% copper and 2% chromium. It is austenitic in structure, so that it will not only withstand corrosion, but will also offer a highly satisfactory resistance to erosion and abrasion. The analysis of the iron may vary in accordance with the purpose, and in certain instances the copper percentage may be eliminated. The material is only supplied in the cast form, but it is readily machinable. Typical uses in the cement field are hoppers, chutes, kiln and dryer parts.

A third type of iron contains 3.0–3.2% carbon, 0.5–0.7% silicon, 0.6–0.7% chromium and 1.0–1.25% nickel. This has been specially developed for grinding balls in ball and tube mills, especially where the ball diameters are less than 5 in. Such balls are not, however, to be used in a low discharge mill, as breakages may occur in these circumstances. Thousands of tons of balls of this type have proved satisfactory in service.

Another nickel-chronium alloy iron is extensively used for liners in ball mills of less than 7 ft. diameter. The analysis of this material is 2.9–3.2% carbon, 0.7–0.5% silicon, 0.75–1.25% manganese, 4.5% nickel and 1.6–1.8% chromium. The hardness of the iron is about 500–525, when sand-cast. Their characteristics can be improved by a stress relief annealing.

A similar iron, slightly lower in chromium content, and slightly higher in silicon, is used for chill-cast liners for clinker-crushing mills. Usually, the analysis of this iron is modified in order to secure a depth of chill with a grey background. The hardness of this chilled iron is from 650–700 Brinell. Annealing is necessary here, also.

As an example of the use of this material, it may be mentioned that in one instance, three grizzleys for crushing coal and coke, recently installed in an Australian works, each contained 221 of these alloy iron segments. Another use to which it is put is for roll heads employed in grinding cement clinkers. It is claimed that for this purpose it has given from 4 to 8 times the life of plain chilled iron roll heads. In one cement plant grinding clinkers, whereas plain-chilled, iron heads gave an average life of 600–700 hours, the nickel-chromium alloy heads gave an average of 4,000 hours. In yet another cement plant, heads of this type were still in use after a period of 15 months, as compared with a life for the plain-chilled iron heads of a mere 4–5 months. A maximum life of 9,500 hours in grinding cement clinkers is claimed for one head, as compared with a maximum life of 1,000 for the best plain-chilled iron head. These figures speak for themselves.

The roll heads manufactured from this nickel-chromium iron cannot be easily machined, so that the shaft hole has to be cored out and finished by grinding. If the centre of the castings has to be machined, it is necessary to cast against a chill, and an iron with only 2.5–3.5% nickel and 0.75–1.0%chromium is usually employed.

Used for crushing balls, nickel-chromium cast iron has also shown its value. The abrasion resistance as compared with that of steel balls in grinding coal was higher. In three weeks, 2,100 tons of coal were ground in a special mill, and the iron balls were hardly worn, whereas the steel mills were found to be elliptical. After 9,000 tons had been ground, the alloy iron balls were slightly egg-shaped, but their diameter was an inch greater than that of the steel balls. Its adaption to the grinding of cement materials is being considered.

It must not be assumed that the list of irons contained in this brief review comprises the entire range available for use. Not only have nickel-chromium-molybdenum and copper-chromium-molybdenum alloy irons their advocates, but vanadium cast irons are also being marketed, particularly in the United States of America. If, however, detailed reference to these variants is not made here, it is because they have yet to establish themselves firmly in the cement quarry and mining fields, the claims made for them not yet being so closely substantiated by facts and figures as in the case of the nickel and nickel-chromium alloy irons.

Nor must it be assumed from these notes that the alloy irons are in all circumstances capable of replacing steel castings. A great deal depends upon the conditions of use, and wherever severe shocks of an impact character are likely to be met it is advisable to use suitable steels, although alloy irons have given good service in more than one difficult case.

Business Notes and News

International Air Congress.

An International Air Congress is to be held at Stratford-on-Avon from July 8 to July 13, 1940. It is being organised by the Royal Aeronautical Society, and facilities will be arranged for the presentation of papers and for subsequent discussions on technical aspects of aviation.

A preliminary notice announces that, in addition to technical features, a programme of social entertainments is being arranged, which will include two banquets, a ball, a garden party, luncheon parties and visits to places of historical interest in the neighbourhood of Stratford-on-Avon. Arrangements for hotel accommodation are now being made. A detailed programme will shortly be available, and all who desire to attend this Congress are asked to communicate with the organising secretary, International Air Congress, 1940, 4, Hamilton Place, London, W.1.

Moulding Machine Demonstrations.

British Insulated Cables Ltd. have adopted a novel idea to bring to the notice of potential users the advantages of their electric moulding machines. They have fitted out a new demonstration van with some of these machines, and by means of a portable lead are able to show manufacturers the machines at work. Where sizes are suitable, demonstrations will be given with patterns supplied in the locality in which the van is temporarily stationed. Demonstrations have been given in Sheffield, where the van started its tour of industrial centres.

Most of the demonstrational work is being carried out on a squeeze strip machine, which is the smallest of a set of four standard sizes. This machine takes moulding boxes 22 in. by 15 in with a strip of 3½ in. These standard machines are made with a 3½ in. or 6 in. strip, but they can be supplied having a stripping length up to 10 in.

Potential users of these machines will have the opportunity of having practical demonstrations within a short distance of their own works.

Presentation to Mr. W. B. Lake.

Mr. W. B. Lake, J.P., President of the Institute of British Foundrymen, received a presentation from the employees of Messrs. Lake & Elliot, of which he is Governing Director, on the occasion of his 70th birthday. The presentation, which took the form of a silver salver and tankard, was made by Mr. E. A. Clarke, the oldest member of the staff and sales manager, in a few well-chosen words. In replying, Mr. Lake said that when he started the Braintree business 43 years ago, the first employee was a boy, and he little thought that when his 70th birthday arrived that small boy would make him the splendid gifts on behalf of the workmen. Neither did he dream that the business which he started with two men and a boy would develop to its present size of nearly 750 people, and supply important castings, components, and accessories to the motor trade, the engineering industry, War Office, Admiralty, and Air Ministry.

Further Progress in Iron and Steel Production.

Steel operations in June were more than maintained in comparison with the record production in May. The total output was 1,175,600 tons, compared with 1,218,110 tons in May, but the daily output during June was slightly higher at 45,215 tons, against 45,115 tons in May. June represented 26 working days, whereas there were 27 in May. In trade circles last month's production is regarded as very good because a number of plants were out of production undergoing repairs; other furnaces, however, had been put into operation, and at the end of June 356 steel furnaces were on production compared with 335 at the end of May. The total output for the half year is 6,405,600 tons.

There has been a marked increase in the rate of pig-iron production following the starting up of thirteen stacks in May and another last month. The total now in blast is 114. The output for June totalled 715,700 tons, comprising 111,200 tons of hematite, 476,500 tons of basic, 98,600 tons of foundry and 15,400 tons of forge pig iron. The daily rate works out at 23,860 tons against 22,325 tons in May. The total output of pig iron for the half year is 3,636,800 tons.

Shipbuilding Expansion.

There is considerable evidence that the shipping and shipbuilding proposals of last March have effected a transformation in the position of British shipyards. At that time shipbuilding was in a depressing state, whereas the June reports are, by comparison, very cheerful reading. Since March 31 there has been a sharp rise in the tonnage of vessels upon which work was commenced during the quarter, from 330,924 tons to 402,080 tons. The tonnage of vessels at present under construction is 791,000 tons, and although this is less by 246,000 tons than the corresponding figures for June, 1938, a considerable increase is confidently expected by the end of the year. It should be borne in mind that the figures given exclude naval work which also shows a considerable increase.

There is no doubt that shipyards will remain busy for some time to come, and the tendency is for a further increase in tonnage on the stocks.

New Non-ferrous Tube Works Proposed.

A scheme, sponsored by Mr. Gilbert Evans, is under consideration by H.M. Government, for the installation of a non-ferrous tube works in Pembroke Dock. The primary aim is to manufacture copper shell driving bands, and so relieve the makers of non-ferrous tubes to enable them to concentrate on condenser, steam, locomotives and other necessities. Mr. Evans aims at taking over a site 280 ft. by 240 ft., situated adjacent to the G.W.R. branch to the Royal Dockyard, with the assistance of the Development of Trade Association of Wales and Monmouth.

The proposed works would enable smaller manufacturers to obtain supplies to their own specification. The plans and layout of the works are under consideration by the Minister of Supplies. The plant contemplated would be similar to that supplied to a number of firms both in Great Britain and overseas countries.

Honeywell-Brown's New Offices and Works.

Honeywell-Brown Ltd.—manufacturers of controlling and recording instruments—have moved to new offices and works at Wadworth Road, Perivale, Greenford, Middlesex. Their new telephone and telegraphic addresses are Perivale 5691 and Minnreg, Greenford, respectively. This development, states Mr. J. J. Fraser, director, is necessary as a result of continual expansion of business. It will permit a considerable amount of manufacturing and assembly to be carried out in this country.

A further development takes effect on August 1, when Honeywell-Brown's English Company, under the direction of Mr. Fraser, will take over the control of branch offices in Sweden and Holland, as well as of the various distributors and agents in other European countries. The wide range of recording and controlling instruments manufactured by this firm include every type: they are designed to give greater efficiency and increased economy in fields for air conditioning, heating and ventilating, covering practically all industries.

Sub-Station Equipment for L.N.E.R. Suburban Extensions.

In connection with the electrification of the London and North Eastern suburban lines from Liverpool Street and Fenchurch Street to Shenfield, an important contract has been placed with The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

This contract covers plant and switchgear to be installed in six sub-stations and three sectionalising track cabins. The equipment (except for the supervisory control equipment and the high tension switchgear for two sub-stations) will be manufactured at the Witton Engineering Works of the G.E.C., and includes 14 twin-cylinder air-cooled steel-clad rectifiers, complete with main 33,000-volt transformers, each rectifying equipment being rated at 2,000 kW., 1,500 volts, D.C.; switchgear for controlling the 33,000-volt incoming supply, this including 10 metal-clad units (all of 500,000 kVA. breaking capacity); and approximately 77 high speed circuit breakers, 1,500 volts D.C. A feature of particular interest is that the rectifiers are the first air-cooled steel-clad units to be supplied for service at 1,500 volts.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£95	0	0

ANTIMONY.

English	£71	0	0
Chinese	53	0	0
Crude	41	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11½
Brazed Tubes	,,	0	1	1½
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8¾
*Extruded Brass Bars	,,	0	0	4⅞

COPPER.

Standard Cash		£42	13	9
Electrolytic		49	0	0
Best Selected		48	10	0
Tough		48	0	0
Sheets		80	0	0
Wire Bars		49	15	0
Ingot Bars		49	15	0
Solid Drawn Tubes	lb.	0	1	0½
Brazed Tubes	,,	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal° Powder, nominal	lb.	£0	4	9½
‡Ferro Tungsten° nominal	,,	0	4	8
Ferro Molybdenum° ,,		0	4	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/- per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/- per unit	,,	24	5	0
NOMINAL: 6–8 Carbon, scale 7/6 per unit	,,	23	15	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
†Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	9	2	6
20/30% basis 25%, scale 3/6 per unit	,,	10	17	6
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—						
S. Wales	£1	18	0/£2	1	6
Scotland	£1	10	0/£1	15	0
Durham	—			1	14	6
Furnace Coke—						
Scotland	£1	5	0/£1	7	6
S. Wales	—			1	7	6
Durham	—			1	4	2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£67	0	0
*Commercial Ingots		47	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£12	5	0
N.E. Coast—			
Rivets	—		
Best Bars	12	15	0
Crown Bars	12	5	0
Lancashire—			
Crown Bars	12	5	0
Hoops	13	12	6
Midlands—			
Crown Bars	12	5	0
Marked Bars	15	5	0
Unmarked Bars	—		
Nut and Bolt Bars	11	0	0
Gas Strip	13	12	6
S. Yorks.—			
Best Bars	12	5	0
Hoops	13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11½
†Sheet to 10 W.G.	,,	0	1	0
†Wire	,,	0	1	1½
†Rods	,,	0	1	1¾
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£5	15	6
Foundry No. 1	5	3	0
,, No. 3	5	0	6
N.E. Coast—			
Hæmatite No. 1	5	15	0
Foundry No. 1	5	2	0
,, No. 3	4	19	0
,, No. 4	4	18	0
Silicon Iron	—		
Forge	4	18	0
Midlands—			
N. Staffs. Forge No. 4	5	0	0
,, Foundry No. 3	5	1	0
Northants—			
Foundry No. 1	5	1	6
Forge No. 4	4	17	6
Foundry No. 3	4	18	6
Derbyshire Forge	5	0	0
,, Foundry No. 1	5	4	0
,, Foundry No. 3	5	1	0
West Coast Hæmatite	5	15	6
East ,, ,,	5	15	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.160
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton	£17 11 3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton	£19 12 2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton	£12 1 2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6

f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£36	0	0
,, Braziery	31	0	0
,, Wire	—		
Brass	21	10	0
Gun Metal	35	0	0
Zinc	8	0	0
Aluminium Cuttings	65	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	0	0
Scotland	2	19	0
Cleveland	3	0	0
Cast Iron—			
Midlands	2	15	0
S. Wales	3	2	0
Cleveland	3	12	6
Steel Turnings—			
Cleveland	—		
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	—		
Scotland	1	14	0

SPELTER.

G.O.B. Official	—		
Hard	£10	5	0
English	15	15	0
India	14	5	0
Re-melted	14	10	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£10	10	6
North-East Coast	10	10	6
Midlands	10	10	6
Boiler Plates (Land) Scotland	11	8	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	11	8	0
,, ,, (Marine) ,,	—		
Angles, Scotland	10	8	0
,, North-East Coast	10	8	0
,, Midlands	10	8	0
Joists	10	8	0
Heavy Rails	9	10	0
Fishplates	13	10	0
Light Rails	9	13	6
Sheffield—			
Siemens Acid Billets	10	10	0
Hard Basic .. £8 10 0 to	10	0	0
Medium Basic, £7 12 6 to	7	17	6
Soft Basic	7	7	6
Hoops	11	15	0
Manchester			
Hoops	12	7	0
Scotland, Sheets 24 B.G.	14	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to $\frac{1}{8}$ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅛ in.	,,	0	0	3
,, ,, ½ in. × ⅛ in.	,,	0	1	0

TIN.

Standard Cash	£229	15	0
English	230	0	0
Australian	—		
Eastern	230	5	0
Tin Plates I.C. 20 × 14 box	1	0	3

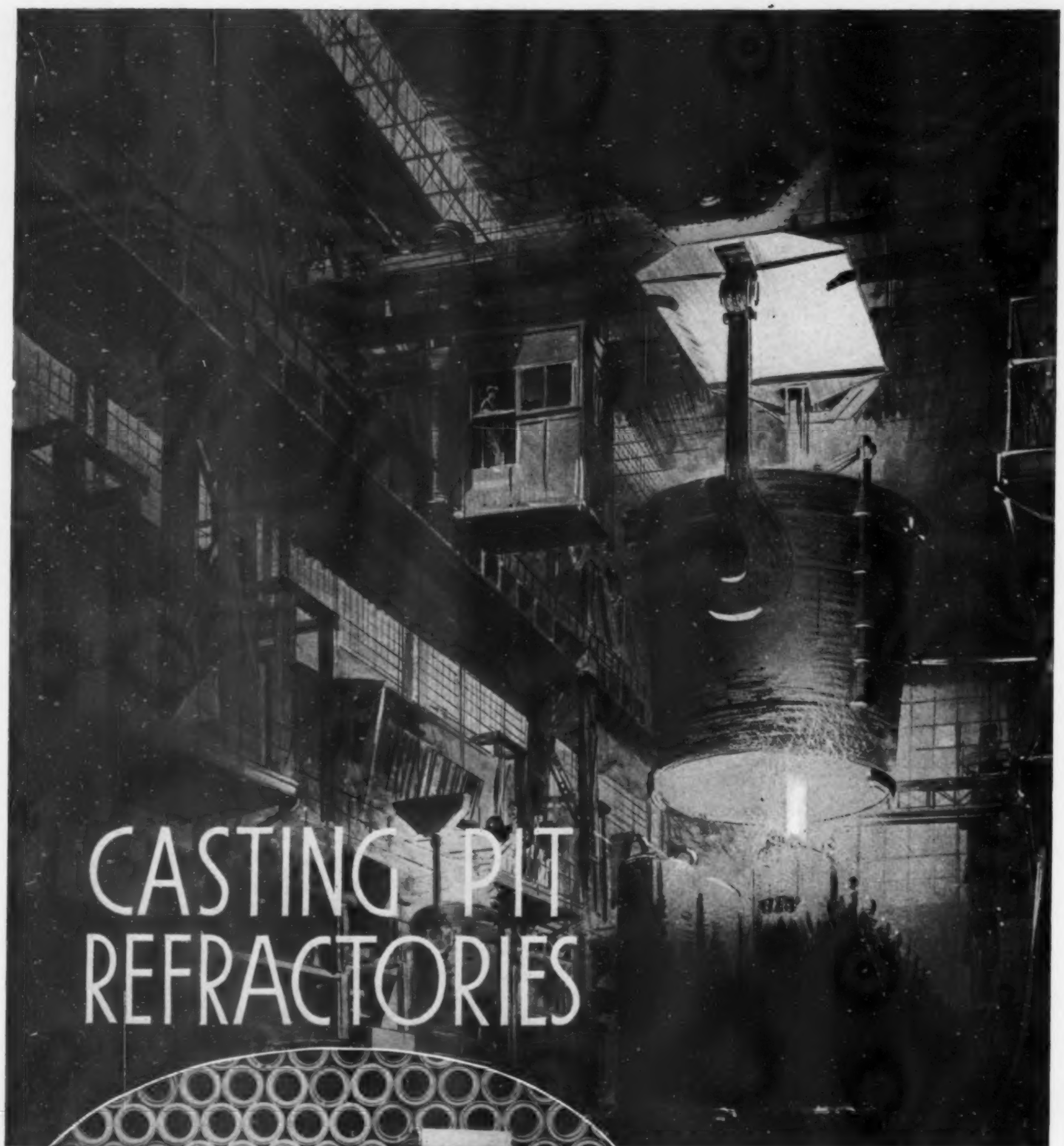
ZINC.

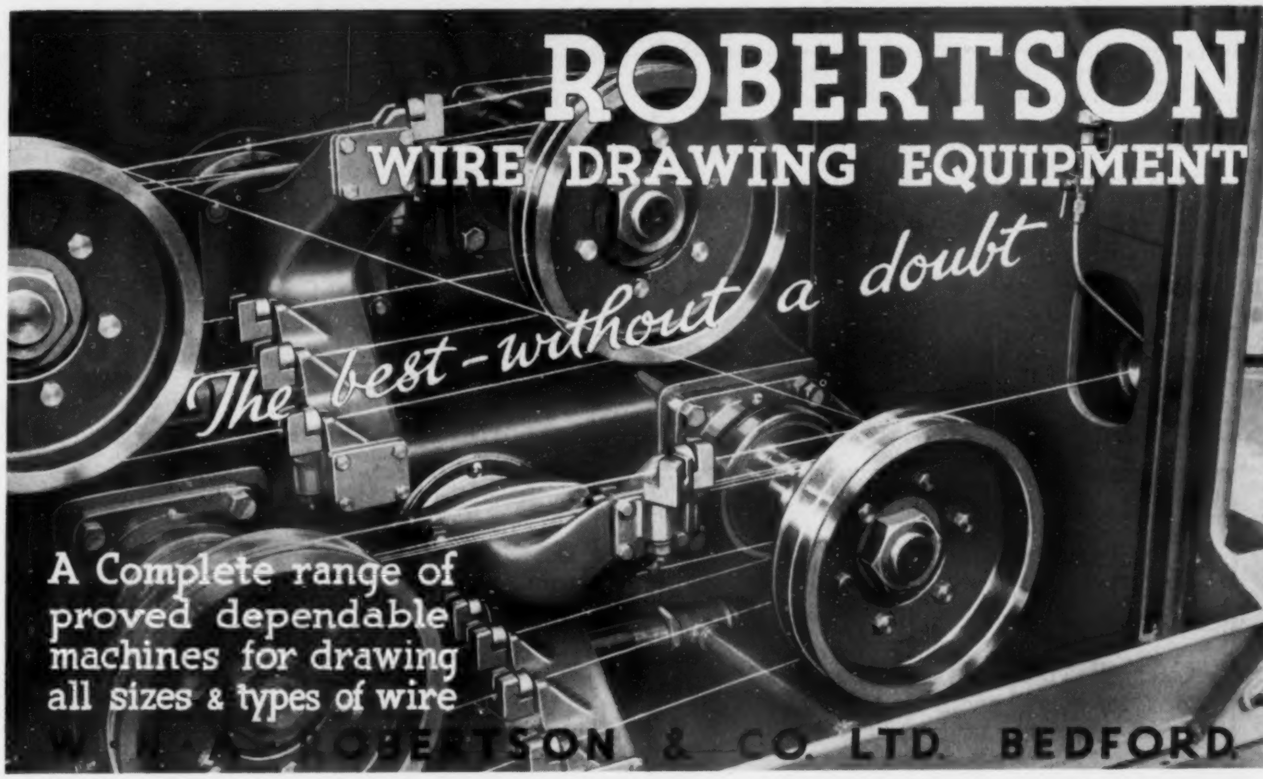
English Sheets	£29	0	0
Rods	18	5	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£14	13	9
English	16	15	0

* McKechnie Brothers, Ltd., July 12. † C. Clifford & Sons, Ltd., July 12 ‡ Murex Limited, July 12.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, July 12. ¶ The prices fluctuate with the price of Tungsten.


CASTING PIT
REFRACTORIES



FILE
THIS
IN YOUR
CABINET

You will then be able to refer to contents of previous issues easily.

METALLURGIA.

Contents.

For JULY, 1939.

	Page
New Laboratories for the British Non-Ferrous Metals Research Association	87–89
This national organisation of producers, manufacturers, and users of non-ferrous metals has developed rapidly and considerable extensions have been made to its laboratories. These extensions and the laboratory equipment are described.	
Research and Development ..	91
The National Physical Laboratory	92
Annual Inspection by the General Board.	
Standardised Aluminium Alloys in the United States. By Robert J. Anderson, D.Sc.	93–94
Some form of standardisation of aluminium and its alloys is essential to ensure control in processing operations and as a check on quality and performance in service. Considerable success has been achieved in America as this article indicates.	
Free Machining Lead-Bearing Steels	95–98
A small amount of lead added to open-hearth steel has no effect upon its physical properties except for slightly reduced grain size, but considerably increases the speed at which the steel can be machined. This type of steel is discussed.	
Chemistry as an Aid to the Production of Sound Castings. By E. Altenhein, D.Eng.	99–100
Steel. By W. J. Brooke	101
The Manifold Uses of Steel. By Dr. W. H. Hatfield	102
Steels Used in the British Railways. By T. H. Turner	103–104
Tinplate and the Canning Industry. By W. E. Hoare, B.Sc.	105–106
Steels in the Automobile and Aeronautical Industries. By W. H. Hatfield, D.Met., F.R.S.	107–108
Applications of Steel Tubing. By a Special Contributor	109–110
Steels for Power Plant. By H. H. Burton	111–113
A selection of steels is discussed which are being used and developed for plant concerned in the raising of steam, its conversion into mechanical energy, and in the conversion of mechanical into electrical energy.	
Modern Tool Steels. By L. K. Everitt, B.Met.	114
Shipbuilding Steels. By J. W. Donaldson, D.Sc.	115–116
Steel Wire. By Alastair T. Adam	117–118
Recent Developments in Materials, Tools and Equipment	119–120
Trends in the Development of Alloy Steels. By Ed. Houdremont	121–123
Attention is directed to the trend of alloy steel development in Germany. The author refers particularly to structural steels, tool steels, stainless and heat-resisting steels, and to special purpose steels.	
The Use of Steel in Heavy Works Plant. By W. Reid	125–126
Application of Alloy Cast Irons to Crushing and Grinding Machinery. By L. Sanderson	126

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd. Imperial Chemical House, London, S.W. 1.

Alloys
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.
J. H. Clifton, London.
Electric Furnace Products Co., Ltd., Norway.

Aluminium and its Alloys
Aluminium Union, Ltd., The Adelphi, Strand, London, W.C. 2.
Earle, Bourne & Co., Ltd., Heath Street South, Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C. 2.
Priestman, T. J., Ltd., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.

Anti-Friction Metals
Addalloy Metal Ltd., 14, Park Lane, Sheffield, 10.
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Billington & Newton Ltd., Longport.
Clifford, Chas. and Son, Ltd., Birmingham.
Earle, Bourne & Co., Ltd. Heath Street South, Birmingham.
Emery Bros., Ltd., Aston, Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co., Ltd., Handford Works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Casehardening
Expert Tool & Casehardening Co., Ltd., London.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
G.W.B. Electric Furnaces, Ltd., Belgrove House, Belgrove St., W.C. 1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Crofts (Engineers) Ltd., Bradford.
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove St., Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Co_2 Recorders
Honeywell Brown, Ltd., 70, St. Thomas St., London.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Rd., Middlesbrough.

Crucibles
Morgan Crucible Co. Ltd., Battersea Church Rd., London, S.W. 11.

Diecastings
Diecastings, Ltd., Moseley Rd., Birmingham 12.

Electrodes
British Acheson Electrodes, Ltd., Sheffield.

Extruded Rods and Sections
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C. 6, Imperial Chemical House, London, S.W. 1.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Rd., Manchester.
Thos. Wilkinson & Co., Ltd., Middlesbrough.

Fuel Oils
Shell-Mex & B. P. Ltd., London.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Elektrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G. W. B. Electric Furnaces, Ltd., Belgrove House, Belgrove St., London, W.C. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Rd., London, N. 7.

Furnaces (Fuel)
Brayshaw Furnaces Ltd., Manchester.
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., Hillington, Glasgow.
Cassel Cyanide Co., Ltd., Room 170r2, Imperial Chemical House, London, S.W. 1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.
King, Taudevin & Gregson, Ltd., Sheffield.
Manchester Furnaces Ltd., Manchester.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.
Salem Engineering Co., Ltd., London.
Wellman Smith Owen Engineering Corporation Ltd., Victoria Station House, London.
Furnace Chargers
Thos. Broadbent & Sons Ltd., Huddersfield.
Fused Blocks
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.
Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.
Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
Shorter Process Co., Ltd., Savile St. East, Sheffield.
Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.
Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Ironfounders.
Craven Bros. Ltd., Reddish.
Joshua Bigwood & Son, Ltd., Wolverhampton.
Machinery
Joshua Bigwood & Son, Ltd., Wolverhampton.
Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.
Magnesium Alloys
F. A. Hughes Ltd., London.
Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.
Magnetic Separators, Clutches, Chucks, and Lifting Magnets
Electromagnets, Ltd., 48, High St., Erdington, Birmingham.
Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.
Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Non-Ferrous Metals
Birmetals, Ltd.
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Perry Barr Metal Co., Ltd., Birmingham.
Oil Engines
Mirrlees Bickerton & Day, Ltd., Stockport.
Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bradley & Foster, Ltd., Darlaston.
Presses
Eumuco Ltd., Beverley Works, Willow Ave., Barnes, London, S.W. 13.
Schloemann, A.-G., Düsseldorf, Germany.
Protection of Metal Parts for Use at High Temperatures
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.
Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.
Pulverised Fuel Manufacturers
Standard Pulverised Fuel Co., Ltd., 4-5, Norfolk St., Strand, London, W.C.2.
Pyrometers
Cambridge Instrument Co., Ltd., London.
Electroflo Meters Ltd., Abbey Rd., Park Royal, London, N.W. 1.
Ether Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Recording Instruments
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co., Ltd., Abbey Rd., Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Rd., Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield.
Morgan Crucible Co., Ltd., Battersea Church Rd., London, S.W. 11.

John G. Stein & Co., Bonnybridge, Scotland.
Regulators
Honeywell Brown Ltd., 70, St. Thomas St., London.
Rolling Mills
Demag, A.-G., Germany.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2, Victoria St., London, S.W.1
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.-G., Germany.
Karl., Fr. Ungerer., Germany.
Steels
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bochumer Verein A.-G. Germany.
British Rolling Mills Ltd., Tipton.
L. Cameron & Sons, Ltd., Sheffield.
Crofts (Engineers) Ltd., Bradford.
Daniel Doncaster & Sons, Ltd., Sheffield.
Darwins, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
Edgar Allen & Co. Ltd., Sheffield.
Thos. Firth & John Brown, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Hadfields Ltd., Sheffield.
Mills, Exors of James Ltd., Stockport.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.
Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Steel Tubes and Sections
Reynolds Tube Co., Tyseley, Birmingham.
Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.
Temperature Controllers
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co. Ltd., Abbey Rd., Park Royal, London.
Ether, Ltd., Tyburn Rd., Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas St., London, S.E. 1.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.
Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.
Thermostatic Controls
Honeywell Brown Ltd., 70, St. Thomas St., London.
Tube Drawing Plant
Sundwiger Eisenhütte, Sundwig, Germany.
Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

Index to Advertisers.

	PAGE
Addalloy Metal Ltd.	23
Allen, Edgar & Co. Ltd.	32
Aluminium Union, Ltd.	26
Amalgams Company, Ltd.	—
Armstrong Whitworth, Ltd.	—
Associated British Machine Tool Makers, Ltd.	16
Barrow Hæmatite Steel Co., Ltd.	42
Bigwood, Joshua, & Sons, Ltd.	6
Billington & Newton, Ltd.	—
Birmetals, Ltd.	9
Birmingham Electric Furnaces, Ltd.	—
Bochomer Verein, A. G.	33
Bradley & Foster, Ltd.	—
Brayshaw Furnaces Ltd.	6
British Acheson Electrodes, Ltd.	18
British Commercial Gas	—
British Furnaces Ltd.	15
British Insulated Cables	8
British Rolling Mills	Edit. 118
Broadbent Thos. Ltd.	—
Burdon Furnaces	—
Calorizing Corporation, Ltd.	—
Cambridge Instrument Co.	—
Cameron, L., & Sons, Ltd., Sheffield	—
Carborundum Co., Ltd.	3
Clifford, Chas., & Son, Ltd.	18
Craven Bros., Ltd.	—
Crofts (Engineers), Ltd.	39
Darwins Ltd.	38
Demag, A.-G.	25
Demag Elektrostahl	—
Diecastings Ltd.	—
Doncaster, Daniel, Ltd.	—
Dowson & Mason, Ltd.	23
Dunford, Elliott, Ltd., Sheffield	40
Earle, Bourne & Co., Ltd.	24
Electric Furnace Co., Ltd.	22
Electromagnets, Ltd.	24
Electroflo Meters Co., Ltd.	—
Electric Furnace Products Co., Ltd., Norway	—
Emery Bros., Ltd.	—
English Steel Corporation, Ltd.	34, 35
Ether, Ltd.	23
Eumuco, Ltd.	—
Expert Tool & Casehardening Co., Ltd.	—
Firth-Brown, Ltd.	29
Foundry Services Ltd., Birmingham	—
Fox, Samuel & Co., Ltd.	31
Gibbon Bros., Ltd.	10, 11, 12
General Electrical Co., Ltd.	—
G. W. B. Electric Furnaces, Ltd.	—
Griffin, Chas. & Co., Ltd.	46
Hadfields Ltd.	36
Herbert, Alfred, Ltd.	41
High Commissioner Special Areas	21
High Duty Alloys, Ltd.	5
Holroyd, John, Ltd.	—
Honeywell Brown, Ltd.	—
Howden, T. C., & Co.	46
Hughes, F. A., Ltd., London	43
Imperial Chemical Industries, Ltd.	21, 24
Incandescent Heat Co., Ltd.	—
Industrial Art Services, Ltd.	18
Integra Co., Ltd.	—
Jackman, J. W., & Co., Ltd.	—
Kasenit Ltd.	Outside Back Cover
Kent, George, Ltd.	—
King, Taudevin & Gregson, Ltd.	—
Krupp Grusonwerk A.-G.	7
Magnesium Castings, Ltd.	13
Manchester Furnaces	—
Manganese Brass & Bronze Co.	28
Marshall and Co.	44
Maschinenfabrik Froriep	—
McKechnie Brothers, Ltd.	Inside Front Cover
Metallisation Ltd.	—
Metalectric Furnaces, Ltd.	—
Metropolitan-Vickers, Ltd.	—
Mills, W., Ltd.	—
Mill, Exors. of Jas.	Front Cover
Mirrlees, Bickerton & Day, Ltd.	—
Mond Nickel Co., Ltd.	—
National Savings Movement	—
Northern Aluminium Co., Ltd.	19
Perry Barr Metals	—
Priest Furnaces, Ltd.	Inside Back Cover
Priestman, T. J., Ltd.	14
Refined Stainless Steel Co., Ltd.	—
Reynolds Tube Co., Ltd.	Inside Front Cover
Rheinische Walzmaschinen	14
Robertson, W. H. A., & Co., Ltd.	45
Rudge Littley, Ltd.	—
Salem Engineering Co.	46
Sanderson Bros., & Newbould, Ltd.	Edit. 118A
Schmitz, A.-G.	8
Schloemann, A.-G.	17
Shell Mex Ltd.	—
Shorter Process Co., Ltd.	46
Siemens Schuckert	20
Standard Pulverised Fuel	—
Stein, J. G., & Co., Bonnybridge, Scotland	28
Steel, Peech & Tozer, Ltd.	30
Sternol, Ltd.	7
Sterling Metals, Ltd.	—
Thermal Syndicate, Ltd.	24
United Steel Co., Ltd., The	30, 31
Ungerer, Karl Fr.	4
Victor X-Ray Corporation	—
Wallwork, Henry, & Co., Ltd.	—
Wellman, Smith, Owen, Ltd.	—
Wild-Barfield, Ltd.	—
Wilkinson, Thos.	—
Wilson & Hudson, Ltd.	48
Workington Iron & Steel Co., Ltd.	—

Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers Limited, Hotspur Press, Manchester; and London.